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ADLAI E. STEVENSON, *Governor*

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DECEMBER 31, 1950

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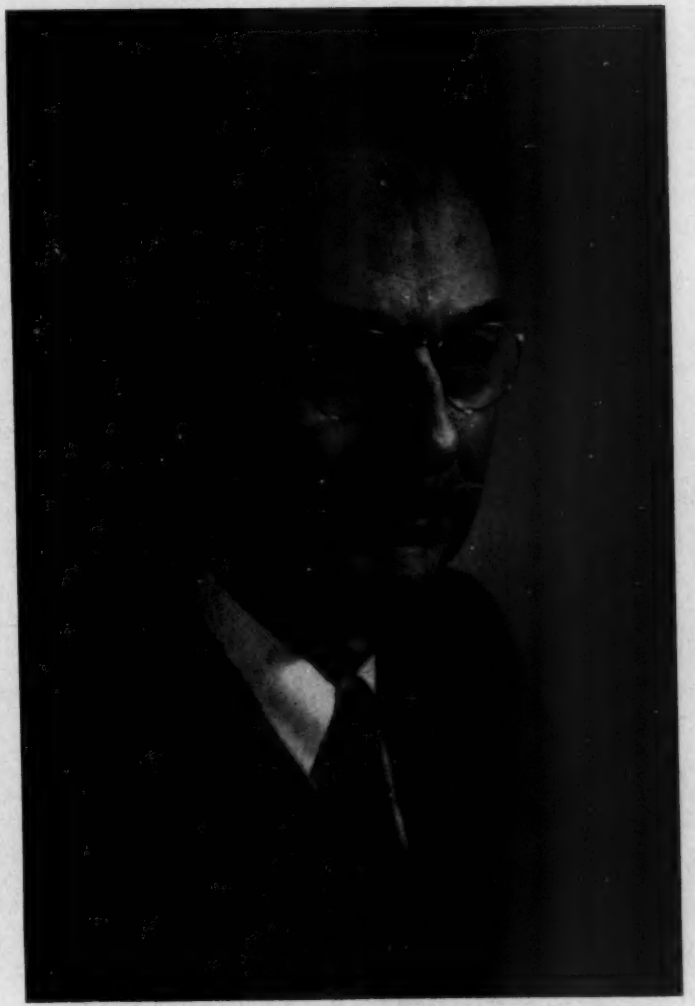


THORNE DEUEL, *President*, 1949-1950

PRESIDENTIAL ADDRESS

A NEW APPROACH TO STUDIES OF CULTURE AND SOCIETY

THORNE DEUEL
President, Illinois State Academy of Science

When I began some months ago to draft an outline for this paper, I was already engaged in writing a booklet in the *Story of Illinois* series of the Museum, called "Man's Venture in Culture" with the subtitle "Some Inventions Underlying Modern Civilization in Illinois." Work on this pamphlet set in motion a train of thought and raised questions that, I suppose, have always puzzled students of man. How was man launched on his cultural and social career and, once started, what kept him on the road? Is culture haphazard and erratic? Is it, as Professor Lowie once said, "a thing of shreds and patches"? Or does it have direction and meaning?

If I seem dogmatic, I hope you will consider that my statements are always qualified by the phrases "in my opinion" or "it seems to me."

The talk you will hear is selected from a larger paper and will consist of three parts:

(1) A broad hypothesis of cultural and social evolution.

(2) A brief survey of man's essential needs and his means of satisfying them as a starting point for studies in culture and society.

(3) A comparison of the means used to satisfy the same need in a simple culture and in the United States today.

Cultural and Social Evolution

For several hundred years, philosophers, historians, and, more lately, scientists have observed, experimented, and amassed vast amounts of data about man, his psychological nature, his cultural and social achievements. The resulting conclusions, even where they deal with significant data, have been disappointing. Consideration of this state of affairs seems to indicate a need for a new approach to the sciences concerned.

It seems almost obvious after considerable reflection on the subject that man's existence may be divided into four periods or stages of cultural and social development, each bounded or limited at beginning and end by a discovery and invention series. Whether or not the individual should be considered as man or wild animal in the first stage is outside this presentation.

Whether or not he should be considered a man in the first stage, he *did* learn to stand up on his hind legs, to walk about in the upright position, to use his hands (instead of his jaws) to seize food and to convey it to his mouth, to throw stones and hit with sticks in self-protection or aggression, and finally to crack rocks and break sticks so that they would better serve his purposes.

Finally he hit upon a discovery—the realization that if he struck a piece of flint in a certain way with a small boulder he always got the same result, a shell-shaped (conchoidal) scar on the rock mass or core. He next visualized how to make a weapon of a certain shape by using his discovery, possibly years afterward, though I am inclined to believe the invention followed close upon the discovery. At any rate he eventually invented a chipped stone tool the type of which was copied again and again. Archaeologists recognize some of his improved types of early stone tool as a fist axe or a chopper.

I shall follow him briefly through the second stage in which he became a family man, learned to talk, and formed loosely knit societies with other men, hunted animals with groups of his fellows, until finally the woman discovered how to grow food plants at home and the man to bring up young animals found during the hunt, to tame and breed them in captivity.

This led man into the age of food production where the family raised their own grain and meat, which was thereby generally more plentiful and certain. He could support larger families than before and live in villages, where he now needed to cooperate with his neighbors and to devise a means of regulating the conduct of families thus living side by side. It was probably the man who had the idea of hitching the bullock or cow to the digging stick that the woman used and thus invented the plow. Over the centuries that followed, food production was accelerated, cities grew, and government and religion became complicated. Man learned to hitch the ox to the mill to grind his corn, or to a wheel to lift water from the river to his fields. The latter part of this stage we usually call ancient history.

Shortly before the beginning of the Christian era man made his third key discovery—that a wheel turned by the power of water could be hitched to his mill and do more and better work than his tame animals. Roughly this coincides with the beginning of Mediaeval and Modern History. I shall not go into the changes that have taken place since that discovery; they are fully described in histories. And it is well known that atomic energy is the latest source of inanimate power man has attempted to harness to the machine.

To summarize, there have been, if my hypothesis is correct, three key discovery-inventions: (1) the discovery that stone could be regularly chipped or flaked and thus tools be made of useful, specialized shape, (2) that plants and food-draft animals could be bred and raised successfully in artificial surroundings, and (3) that inanimate power could be harnessed to machines to do work man had never dreamed of doing before.

The four stages can be called: (1) the brute or pre-cultural stage, (2) the stage of man's self-domestication, (3) the stage of food production, and (4) the machine age or stage of mass production.

Man's Essential Needs

Now let us look at some of man's needs which we can, I believe, agree upon as essential or basic needs. We shall have to disregard, perhaps, for the time being some of our standards of value that we have learned to consider significant. Possibly some of them may be the means of satisfying needs (and not very important ones

at that) rather than actual needs. It may help us in our attempts to separate needs from the means of satisfying them to consider a principle generally accepted among social anthropologists: a going cultural and social group continues to so exist because it provides the means of satisfying the essential needs of the individuals of that group.

The basic needs of man in a cultural and social world and some of the means of satisfying those needs at one period or another of his existence are listed in table I.

TABLE I.

Basic Needs	*Means of Satisfying Needs*
1. Individual security.	1. Pursuits that permit individuals to secure food, water, air, sunlight, housing, clothing. Magic, religion, ethics, science, technology, values, law, order, philosophy and ethics.
2. The opportunity for the individual to develop and fit himself into his surroundings.	2. Curiosity and cautiousness, play activities, education, experience, professional and technical training, clubs, societies, associations, art, literature, theatre, and similar pursuits.
3. Lineage and group continuation.	3. Marriage and marriage customs.
4. Regulation of individuals within groups, and of groups with individuals and other groups.	4. Custom, law, government.

The first three of these are equally the needs of all living things, the last seems to apply to the so-called gregarious and social animals. However, the cultural and social means of satisfying man's needs appear to be of a different kind, possibly best expressed by saying that they exist chiefly on a cultural and social level as against the purely instinctive level of non-cultural animals. Accompanying the needs and the means taken to satisfy them—in fact, the chain on which the needs (instinct or tendency to act) and the means (action or behavior) are strung—is the healthy activity or functioning of the nervous organization. These needs and, to a greater or lesser degree, the identification and acceptance of the means to satisfy them lie in the nervous and physical structure that offspring inherit from their ancestral lineage through their parents. In the multiplicity of details (important to the individual on account of his standards of values concerning his cultural and social surroundings, though not necessarily significant in the eyes of his group or to cultural and social evolution), the means differ widely.

You may think of other needs, but I believe you will agree that those proposed are essential to man today in his world. Individuals, of course, may exist who apparently disregard certain of the basic needs but they are overwhelmingly in the minority and are not important for our discussion nor in cultural evolution.

A Means of Social Regulation

Let us now take a basic need of man and one of the means devised

or invented to satisfy it—the need and means for regulation and guidance. We could equally well have chosen another need and the corresponding means of satisfying it. Whenever the domestication of plants and/or animals was discovered or wherever the invention was learned and put to use by man, sooner or later a number of families gathered and formed communities. Man as a member of such groups found it to the advantage of himself and his family to have a simple regulatory system to give security and equal rights to all families in the village and to protect them from outsiders. Without going into the history of governmental forms, I believe we can classify them all into two broad types, which may be called *the rule of the majority* and *the rule of the minority*. The governments of the United States, Great Britain, and Switzerland belong to the first class; the ancient oriental and mediaeval kingdoms and empires, Russia, and "dictated republics" to the second. It is beside the point to discuss here the relative merits of the two types. From an anthropological standpoint, whichever one works satisfactorily for a group is for that people at that time a healthful way of satisfying their need in this respect.

On account of our interest and general acceptance of its value in the United States, we shall consider here government by the majority or democracy. From our knowledge of man from history and ethnology, it is probable that the earliest villages were governed by a council of all the citizens meeting in assembly. Similar communities in the same cultural stage exist today. Their citizens' councils bear a close resemblance to the New England town meeting. If we examine the significant features of these early third or food production stage democracies we find:

The citizens assemble at the announcement of messengers, or perhaps a town crier announces through the streets the business to come before the assembly. The citizens meet at the appointed hour. A chairman, elected for the purpose, or possibly for the year, calls the meeting to order, puts or calls upon others to put each item of business before the gathering. All citizens are permitted to speak freely about the matter, whether they favor or oppose the issue. At the end of the discussion of each question, a *viva voce* vote is called, first those in favor saying "aye," then those against it saying "no." It was a simple matter to decide, according to the volume of response, which side had won as long as opinion was heavily weighted one way or the other. It was impossible to decide when the assemblies were large and almost evenly divided on an issue, for these early people were unable to count. When villages grew into cities or became countries with considerable outlying territory, these simple democracies were unable to survive and minority rule of the kingship type became the order in western and southern Asia and northern Africa, and later in Europe and most of Africa.

If we were to study the Greek city-states, the Roman and the Swiss republics, we would see how these difficulties of regulating dense populations and extensive territories were gradually overcome and government by the people made practicable under changed conditions. However, let us look at our own United States (table IIb). We in the United States of America believe our form of regu-

TABLE II.

a. *Primitive Village*	b. *United States*
1. The citizens of the village are the governing power, that is they make laws, arrange for their enforcement, punish violators and defend their community.	1. The citizens of the country are the governing power or the source of that power. Men and women over 21 years of age and mentally competent are citizens.
2. The village assembly consisting of all citizens performs the functions of an executive, legislative, and judicial nature, and elect a leader during emergencies.	2 In general the citizens elect by ballot officers and members of legislative and judicial bodies to act for them by performing executive, legislative, judicial, and defense functions in accordance with the general wishes of the electing citizens for a definitely limited term of office. These officers and representatives are responsible to the citizens electing them whether or not they so think and act.
3. The assembly elects a leader to act temporarily for the village in a crisis. He vacates his office and duties when the emergency is over.	3. The powers of certain offices are expanded and/or new officers are appointed in an emergency, for its duration only, after which these powers and offices are reduced again to their usual peacetime limitations.
4. Information is freely exchanged among villagers. Issues are discussed on the floor of the assembly. Minority views are heard equally with all variations of opinion, without restraint or threat of injury.	4. Information untampered with by those temporarily exercising the governing functions is communicated to the citizens by means of newspapers, radio, books, magazines, and other means, so all sides of issues may be known, including international relationships, domestic issues and happenings, and scientific discoveries.
5. Decisions of the assembly are arrived at by *viva voce* voting of qualified voters regardless of which side of the issue they take. Views of the majority are accepted by all and carried out.	5. Decisions are secured in the different governing bodies and the elections by *viva voce* voting or balloting of all qualified voters attending the polls or duly authorized meetings. The minority votes without fear of injury or restraint and the will of majority is accepted by all and carried out.

lating and guiding people's conduct to be as good as, or perhaps a little better than, any other form of control in the world.

There are differences between the tremendously complex organization of government by the majority in the United States today and the very simple democratic form back in western Asia nine or ten thousand years ago. I believe it is not difficult to explain those differences between the two political units in terms of population density, extent of territory, modern complexity of the technological devices and the diversities of the social organization and of thought. Comparing the corresponding features of the two democracies:

(1) The first item is essentially the same in both simple and representative democracies (the governing power rests with the citizens).

(2) In our United States, government by representation is neces-

sary (we know no substitute) because of the enormous number of people and the vast extent of territory involved. How citizens are considered qualified is not very important as long as it is done on a reasonable basis and is acceptable to the group.

(3) In the primitive democracy the headman, or someone elected by the assembly of citizens, would take over in an emergency. In modern democracies it is simpler to increase the powers of officers already functioning although additional officers are also appointed for special work not considered necessary in ordinary times.

(4) Methods of communicating information have changed enormously since the early village democracies through technological inventions, but our present methods serve the same purpose of getting the news promptly to the citizens, now numbering in the millions and scattered over millions of square miles.

(5) Voting *viva voce,* by ballot or by balloting machines, today takes advantage of technological inventions to insure accuracy of results, to speed up the "returns" from millions of people over a wide area. The purpose is still to determine the will of the majority of the citizens, which is accepted by all.

Let me see if I can simplify into single phrases each of the parallel items so that one statement may satisfy the essential principles of a democracy at any time.

1. The governing power resides in all the citizens.
2. The local body of citizens directs the regulatory processes either directly or through representatives elected by them. Issues are discussed and voting on either side of issues is done without fear of injury or threats to intimidate.
3. In times of emergency, officers with special powers may be elected and/or the powers of those in office may be expanded during the crisis only.
4. Information giving both sides of issues is circulated without being colored by officials in office.
5. Each question is decided by the majority of the voters, voting being done in a manner suitable to the conditions of population and territory. The will of the majority is accepted by all.

Summary

Without wishing to belabor my point, it seems to me that a new approach, or a revised approach if you like, is in order in the social sciences.

My proposal is that studies should be made of the essential needs of man and the means of satisfying them in different autonomous cultural and social groups. I suggest the studies be made in the different stages suggested above because I believe such stages exist and are basic in cultural and social evolution. Comparison of suitable (that is, as nearly complete) examples of the means as possible in each stage will, I believe, insure determination of significant features of those means. The significant series of the means satisfying each need in all the stages should be compared again one with another. The result, I believe, in each case will be an identity or near-identity, provided a corresponding means has developed or continued in

each stage considered. The differences, I am confident, will be found in man's increasing means of satisfying his needs, in the changing from one means to another deemed more serviceable, in the changing, over long periods of time, of certain means into needs, and in changes in man's natural and artificial surroundings.

In pursuing the research referred to it will be necessary for the worker to strip from the means of satisfying the essential needs any nonsignificant features, as one who in reorganizing his attic removes the rubbish.

The two fields of psychology and cultural social studies are, of course, closely linked. Nevertheless, it may be possible, after clearing away some of the confusion, to study the psychological processes separately from the cultural and social processes.

WELCOME TO AUGUSTANA

CONRAD BERGENDOFF
President, Augustana College, Rock Island

More than the historians of American education have yet made clear, our schools have received stimulus and contributions from older systems of other countries. Augustana is an illustration of this fact. Seventy-five years ago its faculty was made up almost entirely of men trained in higher schools of Sweden. In 1876 the Swedish government took part in the Centennial Exposition in Philadelphia, and Augustana had the good fortune to secure for its faculty the secretary of the Swedish section, Josua Lindahl, who had his doctor's degree from and had been a teacher at the University of Lund. With his arrival in 1879 the foundations were laid for the natural sciences on this campus. I find in the catalogue of a decade later these statements of how the sciences then were taught here.

Freshman Year:

Botany—Vetegable Histology: Examination of the various kinds of plant tissues; microscopic work; Lectures and Recitations. Vegetable Physiology.

Vegetable Taxonomy—detailed examination of types of respective groups. Martin's *Human Body* was used as a text.

Sophomore Year:

Physics, General and Analytical Chemistry.

Junior Year:

Physiology: Dissection of parts of vertebrate animals to illustrate human anatomy and histology.

Conchology: Study of the specimens in the Lindahl collection of mollusca with a view to identification of genera and families.

Senior Year:

Geology: Lectures and Recitations. Exercises in identification of the more common fossils, minerals and rocks: Four excursions to the nearest exposures of the Quaternary, Carboniferous, Devonian, and Silurian formations. The text was Le Conte's *Elements of Geology.*

I am not competent to compare such a scientific curriculum with that of other American colleges 70 years ago, but I am impressed with the emphasis laid on observation, experiment, student collecting and handling of data, and the division of the material. Still another item of interest was the building and use of the museum. Here a word may be in place concerning Josua Lindahl's contribution, not only to Augustana but to the State of Illinois. As a student Lindahl had worked with the museum at Lund University, and for three years he had served as assistant in the Royal Museum at Stockholm under one of Europe's foremost curators. He had set up the Swedish exhibit at the International Geographical Congress in Paris in 1875, and the following year had the similar assignment at Philadelphia. So it was natural that one of his objectives at Augustana would be the establishment of a good collection.

Here is an extract from the Catalogue of 1886-7.

The Curator spent two months of last summer on the Pacific Coast collecting specimens on the Farallon Islands—a number of interesting duplicates of the collections of the California Academy of

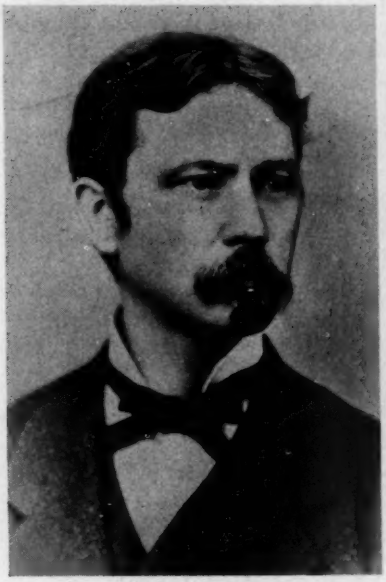
Science were liberally given to him with the prospect of future returns in Illinois specimens—of the lichens collected on the Farallones and in Southern California, which were subsequently sent to the eminent Swedish botanist, Dr. J. Hulting of Norrköping, Sweden, for determination, a series of 16 named species was lately returned to the museum by Dr. Hulting, who had most kindly further increased the collection by adding 17 species of Swedish lichens—a set of fragments, comprising 350 species of minerals and rocks have been purchased from Prof. A. E. Foote of Philadelphia—a card catalogue of the contents of the museum is being prepared. Thus far only the *Testudinata* and *Ophidia* are completed, while the other vertebrates, the crustaceans and the worms, are still under operation. Notwithstanding the present crowded quarters of the museum, it is made available for study, and besides a constant use of specimens in the regular classwork, special studies of various branches of the collections have been made by several students.

In 1888 Dr. Lindahl moved to Springfield, on his appointment as Curator of the State Library and Museum.

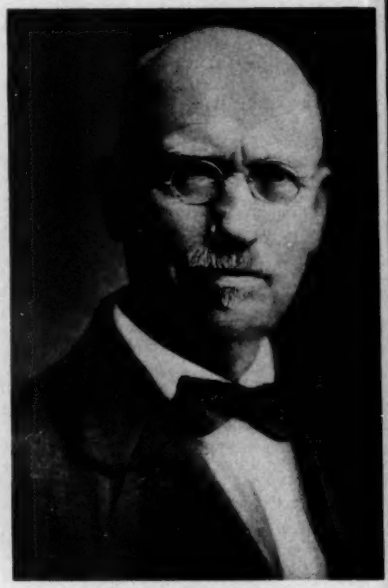
It is not my intention to impose on you a history of the sciences on this campus. But we want you to know that you come to an institution which is interested in your work. I take it that Augustana's origin as a church institution is known to you, and there may be some who wonder if religion and science have been friends here. May I assure you that throughout its 90 years they have been closely related, and that there has been no controversy between them. I have mentioned Josua Lindahl because he typifies the spirit of this campus in this matter. Himself a minister's son, he argued for a close alliance between the teachers of science and the teachers of religion for the good of both.

I like to think that there was a relationship between Lindahl and that great Swedish botanist, Linnaeus, whose devotion to science none would question and whose motto was the words of Ovid, "Innoque vivito, Numen adest" (Live without reproach, God is present). The tradition in which Lindahl worked—and which he transferred to this campus—gave to the facts of the physical universe a significance which derived from more than human reason. A biographer of Pascal has described the parallel interests in the words "laboratory" and "oratory"—in the older sense of that word, namely prayer. To know the world in which man lives, to know the God to whom man prays, this seems to us to encompass a liberal arts education. Therefore religion and philosophy as well as the natural sciences are free on this campus to bring their own methods and insights to the complete training of American youth.

In that spirit we welcome the Illinois Academy of Science to hold its 43rd Annual Meeting in our halls, hoping together with you to realize the fellowship and good will wherein truth may flourish.



JOSUA LINDAHL



JOHAN AUGUST UDDEN

THE LINDAHL-UDDEN MEMORIAL BOULDER

DEDICATION OF LINDAHL-UDDEN MEMORIAL

M. M. LEIGHTON
Chief, Illinois State Geological Survey, Urbana

Address presented at the dedication of the Lindahl-Udden Memorial, Augustana College, May 5, 1950*

We treasure these golden moments, set aside at the close of the day's program of the Illinois State Academy of Science, to do honor to two great men of science, Josua Lindahl and Johan August Udden, who belong to the early days of Augustana College. These two names are indelibly written in the annals of this College and in the memories of a host of scientists throughout the nation.

Josua Lindahl

If Josua Lindahl were living now he would be called a zoologist by zoologists and a paleontologist by geologists. He had the breadth of interest of the natural scientist. He was the first to occupy the chair of Natural Science at Augustana College.

It takes little imagination to realize the problems that faced the college authorities of that day in choosing a man to trust with the introduction and the development of a curriculum in science. From the beginning this institution has emphasized the acquisition of both wisdom and knowledge, a rounded value which calls for exceptional administration and mature teaching.

This was in 1878 and Lindahl was 34 years old. The Swedish government had sent him to the Centennial Exposition in Philadelphia in 1876 as Assistant to the Commissioner-General in charge of the Swedish exhibit. For a while after the exposition closed Lindahl was placed in charge of Philadelphia's new Permanent International Exhibition. Actually his department was the only one that was ever completed; the plan soon failed for lack of funds. Augustana College and Theological Seminary saw in him an enthusiastic scientist and a devoted man, and, it is said, he became the first professor at the college who was not a minister. He brought with him his bride, Sophie Pahlman, whom he had returned to Sweden to marry in 1877. Four children were born to them while they lived at Augustana; the oldest died at an early age.

A. R. Cervin, who loved botany, had already created interest in the subject at Augustana. He taught botany for a year or two in addition to his other technical subjects. It is believed that Lindahl's decade of service at Augustana placed scientific instruction on a firm basis.

Lindahl was the son of a clergyman of the Lutheran State Church. His father died when Josua was 10 years old, and he was sent to live with relatives in Karlshamn.

* The writer acknowledges the helpful services of Professor F. M. Fryxell of Augustana College and Miss Ruth Kerr of the State Museum for making available much basic material for preparing this address. References consulted include History of the Swedes of Illinois, History of Rock Island County, Swedes in America, Who Was Who in America, History of Illinois State Museum of Natural History, publications of Augustana College and publications of the Illinois Geological Survey, American Association of Petroleum Geologists, and Geological Society of America.

While a student in Karlshamn, preparing for the university, he assisted a professor in compiling the flora of the Province of Blekinge, and also collected a large herbarium and made the beginning of a good collection of Swedish land and fresh water shells which he later gave to the Augustana College Museum.

Throughout his stay at the University of Lund, he partly supported himself by private tutorship in the Von Essen family. He received further assistance by being once awarded the Thonander Stipend, voted once a year by the student body to the most worthy of their members. He also worked in the Museum of the University of Lund where he contacted Gwynn-Jeffreys, the British conchologist, who later invited him to use his pleasure yacht in order to make zoological dredgings off the west coast of Ireland. This was followed by an expedition under the auspices of the Royal Society of London to carry out the first deep-sea explorations in the Atlantic, and later in the Mediterranean.

The following year, 1871, he was zoologist of an expedition sent by the Swedish Academy of Science to make explorations in Greenland and to bring back massive blocks of meteoric iron which had been discovered the previous year. He also took part in dredging expeditions the two following summers along the coast of Sweden to study the prevalence and distribution of invertebrates which served as food for fish.

After Lindahl received his doctorate he taught zoology at the University of Lund until he was sent to Philadelphia. The background shows ample reasons why he was brought to Augustana. Lindahl remained at Augustana as Head of the Department of Natural Science for ten years, where he built up a strong sentiment for the study of science, and reflected his fame upon the department. The New Main Building for the teaching of science was completed in 1888 before he left Augustana.

After the death of Professor A. H. Worthen in May 1888, who had been State Geologist of Illinois since 1858, Lindahl accepted the commission as Curator of the State Historical Library and Natural History Museum at the State Capitol in Springfield. The State Museum had been established in 1877 and Worthen was made Curator. He had retained the title of State Geologist in spite of the fact that appropriations for the Geological Survey had ceased in 1872 except for publications of the work already done. The Curator was required by law to perform the duties of State Geologist. Upon assuming office Lindahl, acting as State Geologist, prepared Worthen's last report for publication (Volume VIII of the Geological Survey of Illinois), and added a revised index and a reproduction of the geological map, then out of print, on a small scale. Lindahl deeply appreciated Worthen's magnificent work and in his letter of transmittal to Governor Joseph W. Fifer he outlined a sound program for future Geological Survey work. This, however, was not acted upon.

There was much interest in the forthcoming Columbian Exposition in Chicago and Lindahl prepared a geologic exhibit for the Illinois State Building and had charge of it until July.

Lindahl devoted his entire energies to the work of the Museum. He had never regarded his office as political, but after the election of a new State administration his resig-

nation was called for and his term of office ended in July 1893, after five years of tenure. After this unfortunate incident, Lindahl taught for two years in Chicago and then became Director of the Cincinnati Society of Natural History beginning in December 1895. As Director, he edited the Journal of the Cincinnati Society of Natural History until 1906 when at the age of 62, he moved to Chicago where he lived until his death in 1912.

The special esteem given Lindahl was shown by the high honors he received from the Government of Sweden; he was made Officier d' Academie in 1875 and was decorated by King Oscar II with the Royal Order of Vasa in 1877. As a biologist he showed unusual breadth of interest, carrying membership in both the American Society of Vertebrate Paleontologists and the American Society of Invertebrate Paleontologists.

Johan August Udden

Johan August Udden succeeded Lindahl at Augustana College in 1888. He was an Augustana graduate of the class of 1881, a student of Lindahl and a member of Professor Cervin's first class in botany.

Like Lindahl, Udden was born in Sweden but was Lindahl's junior by 15 years. He came to Minnesota with his parents in 1861 at the age of 2 years.

From his graduation at Augustana, at the age of 23, he went to Bethany College, Kansas, as one of its founders and one of its first teachers. He taught many subjects there and also edited the local paper; indefatigable work characterized his whole career. In 1882, early in his teaching assignment at Bethany, he married Johanna Kristina Davis, who was his helpmate throughout his life. One daughter and three sons were born to them. The daughter died while still very young and two sons died in manhood, Jon, the geologist, and Anton, the meteorologist and physicist. His son Svante became a businessman.

Udden filled the chair of Natural History and Geology at Augustana from 1888 to 1911, a period of 23 years. He taught various courses in botany, zoology, astronomy, physiology, meteorology, and geology, and at times helped out in other fields. He founded a series of monographs, Augustana Library publications, contributing five of the volumes. He published a total of 46 papers during his professorship besides carrying a teaching burden that today would be considered unfeasible for a research man. This is all the more noteworthy in view of his limited professional scientific training. which in addition to what he received at Augustana included a part of the year of 1886 at the University of Minnesota. It was necessary for him to rely on his own powers of observation and reasoning and to devise his own methods of approach and technique. Throughout his life he constantly turned up something new.

At Augustana he wrote fundamental papers on the deposition of dust from the atmosphere, the mechanical composition of clastic sediments, and the sedimentary cycles of the Pennsylvanian period. He brought out, too, that much could be learned about the subsurface rocks by the minute examination of well cuttings, and he was a pioneer in that field.

After he had written in the 17th annual report of the United States Geological Survey, "An Account of the Paleozoic Rocks Explored by

Deep Borings at Rock Island, Illinois and Vicinity," had prepared a geologic section of northern Illinois in the report of the World's Fair Commissioners, and had become know for his exact and original work, he was selected by Director H. Foster Bain as one of the first geologists on the new scientific staff of the new Illinois Geological Survey in 1905. Previously he had served as special assistant on the Iowa Geological Survey from 1897 to 1903, and gave temporary service to the University of Texas in 1903-04. His reports for the Illinois Survey are held in high regard to this day.

Udden developed a love for Texas during his field work in west Texas in 1903, and was persuaded to become a geologist on the staff of the Bureau of Economic Geology and Technology at the University of Texas in 1911, of which he became director in 1915. His contributions to the geology of Texas became as outstanding as they had been to Illinois and Iowa. Udden had already developed the anticlinal theory of origin of quicksilver deposits in 1904 in his study of the Terlingua deposits, and he had already written a masterpiece in his "A Sketch of the Geology of the Chisos Country, Brewster County, Texas," which he finished in 1905. Udden established the first subsurface laboratory in Texas and various oil companies followed his action. By studies in his own laboratory of drill cuttings from the great Permian basin of the Southwest, he discovered the occurrence of potash deposits which convinced him that Texas and New Mexico probably contained workable reserves, a conclusion since confirmed by the development of a large industry in New Mexico.

It is well known that he was the first to advise the regents of the University of Texas of the probable occurrence of oil and gas on the lands of the University of Texas in Reagan County. This led to the discovery of the Big Lake oil field, the forerunner of other west Texas and New Mexico fields. Revenue from its oil lands have amounted to many millions of dollars for the University.

In the teens of this century, Udden became convinced that geophysical research would be useful in leading to the discovery of new oil and gas fields. However, he delayed his publication until 1920. Since then these methods have proved to be of inestimable value in America and elsewhere. His "Review of the Geology of Texas" in 1916 with the first large scale geologic map of the state became geology's "best seller," requiring several editions that totaled more than 50,000 copies. It appeared in time to anticipate the boom in Texas oil during the First World War.

Udden's policies as Director of the Bureau of Economic Geology were born of his own personal integrity. The Bureau never engaged in propaganda for its own benefit nor has it lent itself to be the servant of any special interest. Along with his intellectual honesty went the modesty of a scientist and human kindliness. He gave of his mind and heart to enrich and better the world, a true criterion of the spirit that entered into the founding of his Bethany College.

Udden was one of the first to be made an honorary member of the American Association of Petroleum Geologists and of the Society of Economic Paleontologists and Mineralogists. He was a Fellow of the

Geological Society and of many scientific academies for many years. He earned the degree of Master of Arts from Augustana College in 1889 and was honored by his Alma Mater with the honorary degree of Doctor of Philosophy in 1900 and Doctor of Laws in 1929. Bethany College conferred upon him the degree of Doctor of Science in 1921, and Texas Christian University repeated the honor in 1923. King Oscar II of Sweden knighted him with the Order of the North Star in 1911 when he left Augustana for his new field in Texas.

And now recognizing the rare good fortune of Augustana College in having chosen Lindahl to occupy the first chair of Natural Science and in having produced and accepted Udden as her own son and distinguished scientist, we invite with reverence Dr. Udden's grandson, Marshall Udden, to withdraw the veil from this boulder, on which is inscribed the two names, "Lindahl" and "Udden," which we trust will perpetuate for the long future our tribute to them and which will always bring honor to Augustana and inspire its students and faculty.

So when a great man dies,
For years beyond our ken,
The light he leaves behind him lies
Upon the paths of men.
—Henry Wadsworth Longfellow

THE BEGINNING OF THE ILLINOIS STATE ACADEMY OF SCIENCE*

WILLIAM M. BAILEY
Southern Illinois University, Carbondale

By the middle of the nineteenth century, interest in different fields of science was growing in Illinois, as in other states. Various scientific organizations were formed, some limited to certain sciences, others to local situations. In the former group may be mentioned the first Geological Survey of Illinois (7), which began in 1851, the Illinois State Agricultural Society (6), which was organized at Springfield in 1853, the State Natural History Society of Illinois (2), which was organized at Bloomington in 1858, and the present Illinois State Geological Survey (1), organized in 1905. In the latter group the Chicago Academy of Sciences (3), organized in 1857, was preeminent, and other local scientific organizations may be noted. The Ottawa Academy of Natural Sciences (10) was founded in 1866. The Peoria Scientific Association (4) was organized in 1875. From a clipping from the Peoria *Journal-Transcript* of May 24, 1936, the following statement was taken: "As early as 1839 the Peoria Scientific and Historical Society was in existence." The Peoria Academy of Science of the present time was organized in 1930. The Academy of Science of Southern Illinois (5) was organized at Carbondale December 2, 1876.

As the years passed it came to be recognized as highly desirable that there should be a unification of the scientific interests of the state, and that an organization of those engaged in scientific work throughout the state should be formed. Accordingly, an invitation was extended to all persons engaged in the teaching of the sciences in the universities, colleges, and high schools, and those employed in other lines of scientific work, to meet at Springfield December 7, 1907 (8). More than 100 persons responded, among them a good representation of the leaders in the sciences in the universities.

The meeting was held in the Senate Chamber of the Capitol. The meeting was called to order by A. R. Crook, Director of the State Museum, at 10:00 A.M. U. S. Grant, of Northwestern University, was elected temporary chairman. Secretary of State James A. Rose, on behalf of the Governor of the State, welcomed the group to the State Capitol. T. C. Chamberlin, of the University of Chicago, gave the opening address. Professor Chamberlin introduced his address by extending the felicitations of the Chicago Academy of Sciences, and sketching some of the salient features of its history, covering a period of a little more than fifty years, as a means of suggesting some of the problems that the new academy

* This history of the first few years of the Illinois Academy of Science has been written because of the great scarcity of copies of Volume I and other early volumes of the Transactions of the Illinois State Academy of Science, in order that the membership of the Academy may know something about how the Academy was organized and began its work. The first two annual meetings are included in this sketch. The Committee will appreciate receiving any additional information or comments concerning the early history of the Academy.

would have to face. He then gave an address on the subject "The Advantages of a State Academy of Science." Professor S. A. Forbes, of the University of Illinois, then gave an address on the subject, "History of the Former State Natural History Societies of Illinois."

On motion of S. W. Williston, of the University of Chicago, A. R. Crook was elected temporary secretary. It was voted that the Chair appoint a committee of three on organization. This committee was authorized to add six others to its number. These nine were directed to draw up a constitution and nominate officers. The Chair appointed S. W. Williston, of the University of Chicago, W. A. Noyes, of the University of Illinois, and C. B. Atwell, of Northwestern University. This committee added T. C. Chamberlin, of the University of Chicago; S. A. Forbes, of the University of Illinois; A. R. Crook, of the State Museum; F. L. Charles, of the Northern Illinois State Normal; H. V. Neal, of Knox College; and B. B. James, of James Millikin University. While the committee was at work, there was a general discussion of the plans and aims of the organization. The meeting then adjourned until 2 P.M.

The afternoon session was called to order at 2:15 P.M. by the president pro tempore. The draft of the proposed constitution was presented by S. W. Williston, Chairman of the Committee. It was read by the Secretary of the Committee, F. L. Charles, and was then considered section by section. After revision and discussion the constitution and by-laws were adopted. It was voted that the first annual dues should apply for the year 1908. Chairman S. W. Williston then presented the report of the Committee on nominations. It was voted that the Secretary cast the ballot for the following nominations, and they were declared elected:

President, T. C. Chamberlin, of the University of Chicago.

Vice-President, Henry Crew, of Northwestern University.

Secretary, A. R. Crook, Director of the State Museum.

Treasurer, J. C. Hessler, of James Millikin University.

Third Member of the Publications Committee, H. F. Bain of the State Geological Survey.

Committee on Membership: S. A. Forbes, of the University of Illinois, chairman; T. W. Galloway of James Millikin University; J. P. Magnusson, of Augustana College; C. H. Smith, of the Hyde Park High School; B. B. James, of James Millikin University.

The Membership Committee was authorized to accept as charter members those persons who had previously expressed their desire to be enrolled as such, but were unable to be present at the meeting. The committee acted upon the names submitted. The president-elect, T. C. Chamberlin, was introduced by President pro tempore Grant. B. B. James, of James Millikin University, was appointed treasurer pro tempore in the absence of the Treasurer, J. C. Hessler.

A symposium upon "The Outlook for Young Men in the Various Sciences" was participated in by W. J. McGee, who spoke on "Anthropology," John G. Coulter, of the Illinois State Normal University, on "Opportunities in Botany," W. A. Noyes, of the University of Illinois, on "Openings for Chemists," H. Foster Bain, of the Illinois State Geological Survey, on the "Outlook for Young Men in Geology," Henry

Crew, of Northwestern University, on the "Outlook for Young Men in Physics," and H. V. Neal, of Knox College, on the "Outlook for Young Men in Zoology." Upon motion of W. E. Loomis, of Springfield, it was voted that 500 copies of the proceedings of the Organization Meeting be printed, and that one copy be furnished to each member of the society.

The meeting then adjourned until 8 P.M. In the evening session Dr. W. J. McGee delivered his lecture on the subject "Greater Steps in Human Progress," to an audience of about 600.

The addresses given at the organization meeting were published or reviewed in the first part of Volume I of the Transactions of the Illinois State Academy of Science.

CONSTITUTION AND BY-LAWS OF THE ILLINOIS STATE ACADEMY OF SCIENCE

Adopted at the Organization Meeting at Springfield, December 7, 1907

CONSTITUTION

ARTICLE I. NAME

This Society shall be known as the Illinois Academy of Science.

ARTICLE II. OBJECTS

The objects of the Academy shall be the promotion of scientific research, the diffusion of scientific knowledge and scientific spirit, and the unification of the scientific interests of the State.

ARTICLE III. MEMBERS

The membership of the Academy shall consist of Active Members, Non-resident Members, Corresponding Members, Life Members, and Honorary Members.

Active Members shall be persons who are interested in scientific work and are residents of the State of Illinois. Each active member shall pay an intiation fee of one dollar and an annual assessment of one dollar.

Non-resident Members shall be persons who have been members of the Academy but have removed from the State. Their duties and privileges shall be the same as those of active members except that they may not hold office.

Corresponding Members shall be such persons actively engaged in scientific research as shall be chosen by the Academy, their duties and privileges to be the same as those of active members, except that they may not hold office and shall be free from all dues.

Life Members shall be active or non-resident members who have paid fees to the amount of twenty dollars. They shall be free from further annual dues.

Honorary Members shall be persons who have rendered distinguished service to science and who are not residents of the State of Illinois. The number shall not exceed twenty at one time. They shall be free from all dues.

For election to any class of membership the candidate's name must be proposed by two members, be approved by a majority of the committee on membership, and receive the assent of three-fourths of the members voting.

All workers in science present at the organization meeting who sign the constitution, upon payment of the initiation fee and their annual dues for 1908 become charter members.

ARTICLE IV. OFFICERS

The Officers of the Academy shall consist of a President, a Vice-President, a Chairman of each section that may be organized, a Secretary, and a Treasurer. These officers shall be chosen by ballot on recommendation of a nominating committee, at an annual meeting, and shall hold office for one year or until their successors qualify.

They shall perform the duties usually pertaining to their respective offices.

It shall be one of the duties of the president to prepare an address which shall be delivered before the Academy at the annual meeting at which his term of office expires.

The secretary shall have charge of all the books, collections, and material property belonging to the Academy.

ARTICLE V. COUNCIL

The Council shall consist of the President, Vice-President, Chairman of each section, Secretary, Treasurer, and the president for the preceding year. To the Council shall be entrusted the management of the affairs of the Academy during the intervals between regular meetings.

ARTICLE VI. STANDING COMMITTEES

The Standing Committees of the Academy shall be a Committee on Publication and a Committee on Membership.

The Committee on Publication shall consist of the President, the Secretary, and a third member chosen annually by the Academy.

The Committee on Membership shall consist of five members chosen annually by the Academy.

ARTICLE VII. MEETINGS

The regular meetings of the Academy shall be held at such time and place as the Council may designate. Special meetings may be called by the Council and shall be called upon written request of twenty members.

ARTICLE VIII. PUBLICATION

The regular publications of the Academy shall include the transactions of the Academy and such papers as are deemed suitable by the Committee on Publication.

All members shall receive gratis the current issues of the Academy.

ARTICLE IX. AFFILIATION

The Academy may enter into such relations of affiliation with other organizations of appropriate character as may be recommended by the Council and be ordered by a three-fourths vote of the members present at any regular meeting.

ARTICLE X. AMENDMENTS

This constitution may be amended by a three-fourths vote of the members present at an annual meeting, provided that notice of the desired change has been sent by the Secretary to all members at least twenty days before such meeting.

BY-LAWS

I. The following shall be the regular order of business.

1. Call to order.
2. Reports of officers.
3. Reports of standing committees.
4. Election of members.
5. Reports of special committees.
6. Appointment of special committees.
7. Unfinished business.
8. New business.
9. Election of officers.
10. Program.
11. Adjournment.

II. No meeting of the Academy shall be held without thirty days' previous notice being sent by the Secretary to all members.

III. Fifteen members shall constitute a quorum of the Academy. A majority of the Council shall constitute a quorum of the Council.

IV. No bill against the Academy shall be paid without an order signed by the President and Secretary.

V. Members who shall allow their dues to remain unpaid for three years, having been annually notified of their arrearage by the Treasurer, shall have their names stricken from the roll.

VI. The Secretary shall have charge of the distribution, sale, and exchange of the published Transactions of the Academy, under such restrictions as may be imposed by the Council.

VII. The presiding officer shall at each annual meeting appoint a committee of three who shall examine and report in writing upon the account of the Treasurer.

VIII. No paper shall be entitled to a place on the program unless the manuscript or an abstract of the same shall have been previously delivered to the Secretary.

IX. These by-laws may be suspended by a three-fourths vote of the members present at any regular meeting.

The first regular annual meeting of the Illinois State Academy of Science was held in the James Millikin University, at Decatur, February 22, 1908 (8).

The meeting was called to order by the President of the Academy, Dr. T. C. Chamberlin, of the University of Chicago, at 10 A.M. There were 96 persons present. The Treasurer of the Academy, Dr. J. C. Hessler, of James Millikin University, made an announcement concerning the payment of dues, and also one concerning the plans for the meeting. Prof. S. A. Forbes, of the University of Illinois, Chairman of the Committee on Membership, reported a list of names of persons properly nominated and recommended for membership. These persons were voted into the organization.

The following papers were read in this session:

"Biotic Zones and Districts of Illinois"—Charles A. Hart (Ento-

mology), of the Illinois State Laboratory of Natural History, University of Illinois.

"A Case of Phosphorescence as a Mating Adaptation"—T. W. Galloway (Zoology), of James Millikin University.

"Some Problems Connected With the Coals of Illinois"—S. W. Parr (Chemistry), of the University of Illinois.

"The Desirability of a Systematic Ecological Survey from the Standpoint of Plant and Animal Associations"—H. C. Cowles (Botany), of the University of Chicago.

"A State Ecological Survey"—E. N. Transeau (Botany), of the Eastern State Normal School, at Charleston.

"A Virgin Prairie in Illinois"—H. A. Gleason (Botany) of the University of Illinois.

"Occurrence of Oil and Gas in Eastern Illinois"—H. Foster Bain, of Illinois State Geological Survey.

"Illinois Trees"—T. J. Burrill (Botany), of the University of Illinois.

"Plant Pathology in Relation to Other Sciences"—Ernest S. Reynolds (Botany), of the University of Illinois.

President Chamberlin spoke on the desirability of affiliating with other scientific societies in the State. He gave an account of the discussion at the meeting of the Council, held in Chicago, December 30. He invited those interested in considering plans to meet at 1:45 P.M., before the opening of the afternoon session.

Professor Forbes stated that as a result of the work of many years, a great mass of ecological material had been collected by the Natural History Survey, named and labeled, and that this material was at the disposal of students. He spoke of his gratification because of the increasing enthusiasm for the work.

A. R. Crook, Director of the State Museum, expressed the hope that the Academy would aid the State Museum in securing materials to illustrate the mineral resources of every section of the State, and the relation of animals and plants to each other and to their environment in various parts of the State. C. C. Adams, of the University of Chicago, suggested that a definite work be taken up, so that a report could be made on some locality.

The meeting was then adjourned until 2:00 P.M.

In the afternoon session, which began at 2:25 P.M., the following papers were presented:

"Relation of the State Academy to the Natural History Survey of the Chicago Academy of Sciences"—Frank C. Baker, of the Chicago Academy of Sciences.

"Farm Water Supplies"—Edward Bartow (Chemistry), of the University of Illinois.

President Chamberlin made an announcement concerning the publication of the Transactions, requesting all who were taking part in the program to send copies or abstracts of their papers to the secretary for publication. He expressed the hope that means for publication would be provided by the State Legislature as was customary in other states.

By the passage of a motion offered by H. F. Bain, of the State Geological Survey, the President of the Academy was instructed to appoint a committee of five on the collection of drill records.

A motion, made by S. A. Forbes, was passed authorizing scientific organizations that enter into relations of affiliation with the Academy each to appoint one of its members

to be a member of the Council of the Academy, who should have the right to vote on matters specifically related to the terms of affiliation, but not on other matters. On motion of H. F. Bain, it was voted to invite appropriate organizations each to appoint some member of the organization to represent it on the Academy Council while an ecological survey of the State was being made.

A symposium on "The Atmosphere" was participated in by T. C. Chamberlin (Geology), of the University of Chicago; Albert P. Carman (Physics), of the University of Illinois: H. C. Cowles (Botany), of the University of Chicago; John M. Coulter (Botany), of the University of Chicago; Wm. A. Noyes (Chemistry), of the University of Illinois; Charles E. M. Fischer, of the College of Physicians and Surgeons of the University of Illinois; and H. Foster Bain, of the State Geological Survey.

The meeting was then adjourned.

At the evening session, beginning at eight o'clock, A. A. Michelson, of the University of Chicago, lectured on the subject, "Recent Advances in Spectroscopy."

Abstracts of the papers read at the first annual meeting of the Academy, and the address of Dr. A. A. Michelson in the evening were published in the Transactions of the Illinois State Academy of Science, Volume I, 1908.

The Council meeting of the Illinois Academy of Science was held in Chicago, in the Auditorium Annex, Friday, May 8, 1908, beginning at 2:30 P.M.

On motion of Professor Crew, of Northwestern University, the following committee upon the ecological survey of the State of Illinois was appointed: S. A. Forbes, of the University of Illinois, Chairman; F. C. Baker, of the Chicago Academy of Sciences; H. C. Cowles, of the University of Chicago; H. A. Gleason, of the University of Illinois; and T. L. Hankinson, of the Eastern Illinois State Normal.

The Council voted to publish the "Transactions" of the Academy, which should include the transactions of the organization meeting held December 7, 1907, at Springfield, and the first regular meeting held in Decatur, February 22, 1908, the Constitution of the Academy, and the list of members.

The Council decided to hold the next meeting of the Academy at Springfield, February 20, 1909. It was decided that the program of this meeting should consist of a business meeting and the reading of papers in the morning, a symposium on the scientific activities of the State, their history, methods, and purposes, in the afternoon, and an address by the retiring president in the evening.

The Council then adjourned.

The second annual meeting of the Illinois State Academy of Science was held in Springfield in the Old Supreme Court Room in the State House, February 20, 1909 (9).

The meeting of the Academy was called to order by Vice-President Henry Crew at 10:00 A.M. The minutes of the last meeting were read by Secretary Crook, and approved. The Treasurer, J. C. Hessler, presented his report. This was laid on the Chairman's table until an Auditing Committee could be appointed to examine it. Secretary Crook requested that the members send in their correct addresses, degrees, and the names of the subjects in which they are interested, in order that the records of the Academy might be as complete as possible.

Professor S. A. Forbes, Chairman of the Membership Committee, then presented the report of his committee. This was approved, and the Secretary was instructed to cast the ballot of the Academy for those nominated for membership.

Professor S. A. Forbes, Chairman of the Committee on Ecological Survey, made the following report on the progress of this work.

One of the first tasks of an ecological survey is the recognition and description of the plant and animal associations represented. This may be reached by the detailed study and mapping of limited districts chosen from various parts of the state and representative of much larger areas. The results of this detailed work will give by comparison a general idea of the structure of the associations throughout the state. It may be supplemented by a more general study of the entire state, showing the distribution of such association groups as forest and prairie, sand regions, cypress swamps, etc. Both lines of work lead to the production of an ecological map of the state, showing the distribution of all the associations represented. Survey work of this nature will give appreciable results in a comparatively short time, will indicate the general nature of the survey, will serve as a pattern to amateurs, will open a large field for the use of teachers, and will be a foundation for subsequent investigation. Work on other phases of ecology, such as the correlation of associations with environmental factors or their interrelations with each other, will necessarily accompany the cartographic work to some extent.

Members of the committee reported the following field work under way:

F. C. Baker, ecological study and mapping of limited area at Shermerville, with especial reference to Mollusca.

H. C. Cowles, mapping the plant associations of portions of the South Chicago area.

H. A. Gleason, a study of the vegetation of inland sand deposits.

T. L. Hankinson, the breeding habits of fish near Charleston, correlated with environmental conditions.

V. E. Shelford, ponds in the dune region at the head of Lake Michigan.

E. N. Transeau, plant associations in the vicinity of Charleston; studies of evaporation.

After a discussion of the need of state aid for the survey, it was formally recommended by the committee that,

instead of a separate organization, the Academy cooperate with the State Laboratory of Natural History in securing funds and in carrying out the work of the proposed ecological survey. The State Laboratory has been engaged in this work for years, and is now willing to aid in the survey and to bring together in a comprehensive plan the ecological results of the work of both institutions and individuals.

The committee especially wishes to bring into its membership all persons prepared and disposed to do active work on the ecology of any part of the state.

The report was approved; and the committee was continued for another year.

Chairman Crew then appointed the following committees:

Committee on Nominations—W. F. M. Goss, University of Illinois; F. L. Charles, University of Illinois; S. W. Parr, University of Illinois; T. W. Galloway, James Millikin University.

Committee to Audit the Treasurer's Report—F. R. Watson, University of Illinois; H. O. Barnes, High School, Springfield; R. O. Graham, Illinois Wesleyan University; T. W. Galloway.

The Secretary then stated that a committee to collect drill records was to have been appointed the preceding year. He suggested that this committee be appointed at this time, or a little later in the day. Mr. F. W. De Wolf, Acting Director of the State Geological Survey, suggested Professor J. A. Udden for appointment on this committee, stating that "a great deal of the work is now in his hands." Chairman Crew suggested that, because of the import-

ance of the Committee and the need of further consideration, the appointment of the Committee be postponed until later in the day. This suggestion was accepted.

After some discussion of the desirability of having sectional meetings, the following motion was passed: "That it is the sense of the Academy that we should not resolve our meetings into sectional meetings at this time."

After the conclusion of the business meeting Isabel S. Smith, of Illinois College, Jacksonville, presented a paper on the subject, "Illinois Trees."

In leading the discussion on this paper, Professor Forbes said:

I think the reason the pioneers settled along the streams was because of the shelter, and because most of the earliest settlers came from forest countries. We see, in reading the records of the first explorers, that there was a general prejudice against the prairies, as being bare and lonesome, and practically worthless for agriculture.

Dr. Crook said:

I might say that at the last session a law was passed by the State Legislature designating the 'native oak' as the symbolic tree of this State. If the lawmakers had consulted with some one like Miss Smith they might have found out that there are sixteen varieties of native oaks in this State—another illustration of the fact that our laws would often be better if they were framed by men who availed themselves of the knowledge of experts.

The following papers were then presented without discussion:

"Some Botanical Features of Illinois Sand Dunes"—H. A. Gleason (Botany), University of Illinois.

"Preliminary Report of Observations upon a Robin's Nest"—F. L. Charles (Zoology and Botany), University of Illinois.

"Cliff Flora of Jo Daviess County"—H. S. Pepoon (Zoology and Botany), Lakeview High School, Chicago. Read by title only.

"The Clay Seams of No. 5 Coal Bed in the Springfield Quadrangle"—T. E. Savage (Stratigraphic Geology), University of Illinois.

The meeting then adjourned until 2:00 P.M.

The Academy was called to order at 2:15 P.M. by Chairman Crew. S. A. Forbes, Chairman of the Membership Committee, made a report on additional names of persons proposed for membership in the Academy. The number of new members added at both the morning and afternoon sessions was 42.

The following papers were then presented:

"Hardness of Illinois Municipal Water Supplies"—Edward Bartow (Chemistry), University of Illinois.

"Electrolytic Separation of Metals by Graded Electromotive Forces"—Albert Carver (Physics), Springfield High School.

After the presentation of these papers, Chairman Crew called for reports of committees.

F. R. Watson, Chairman of the Auditing Committee, stated that the Treasurer's report was found to be correct. The Treasurer's report as presented at the morning session was then adopted unanimously.

On making the report of the Committee on Nominations, W. F. M. Goss, Chairman of the Committee, expressed the appreciation of the committee for the efficient work of Vice-President Henry Crew in serving as Chairman of the meeting of the Academy. He stated that Dr. Crew had positively declined to accept the nomination for President of the Academy. He then presented the names of the following nominees for the ensuing year:

For President of the Academy—S. A. Forbes, University of Illinois.

For Vice-President — John M. Coulter, University of Chicago.

For Secretary—A. R. Crook, Director of the State Museum, Springfield.

For Treasurer—J. C. Hessler, James Millikin University.

For the third member of the Publications Committee—H. F. Bain, State Geological Survey.

For Membership Committee — T. W. Galloway, James Millikin University, Chairman; F. L. Charles, University of Illinois; U. S. Grant, Northwestern University; T. L. Hankinson, Eastern Illinois State Normal; S. W. Williston, University of Chicago.

The report of the Committee on Nominations was adopted unanimously, and the ballot of the Academy was cast for the nominees by the Chair.

Chairman Crew then announced the following Committee on Deep Drillings: J. A. Udden, of Augustana College; U. S. Grant, of Northwestern University; and F. W. De Wolf, of the State Geological Survey.

In a symposium on "The Scientific Activities of the State, Their History, Method and Purpose," the following papers were presented:

"State Laboratory of Natural History and the State Entomologist's Office"—S. A. Forbes.

"State Water Survey"—Edward Bartow.

"State Highway Commission"—A. N. Johnson.

"State Geological Survey"—F. W. De Wolf.

"State Museum of Natural History"—A. R. Crook.

After some discussion, a motion was passed unanimously to appoint a committee to secure funds from the State Legislature for the publication of the Transactions of the Academy.

A motion was passed authorizing the appointment of a committee to make a recommendation to be presented to the State Legislature, urging the erection at Springfield of a building to contain the State Museum. Chairman Crew appointed the following committee to take charge of whatever legislative recommendations the Academy thought wise: S. A. Forbes, John M. Coulter, A. R. Crook, and J. C. Hessler. Forbes, Crook, and Hessler of this committee met March 1, 1909, and adopted a report and resolution strongly urging that the State Legislature should take steps to provide an adequate building for the State Museum, either alone or with other appropriate State departments.

The afternoon session of the Academy adjourned until 6:00 P.M., when a banquet was given to the members of the Academy by the Chamber of Commerce of Springfield, in the Y. M. C. A. Building. At the banquet the following addresses were given by members of the Academy:

"Botany and Commerce"—Wm. Trelease (Botany), Missouri Botanical Garden, St. Louis.

"Science and Transportation"—W. F. M. Goss (Steam Engineering), University of Illinois.

"Illinois With or Without Science"—R. O. Graham (Chemistry), Illinois Wesleyan University, Bloomington.

"The Relation of Sciences to Each Other"—Henry Crew (Physics), Northwestern University.

All of the papers presented at this meeting of the Academy and the addresses at the banquet were published in the Transactions of the Illinois

State Academy of Science, Volume II, 1909.

The Council meeting of the Academy was held in the Botany Building of the University of Chicago, November 1, 1909. Those present at the meeting were S. A. Forbes, John M. Coulter, A. R. Crook, and J. C. Hessler.

The following decisions were made concerning the next annual meeting of the Academy. The cordial invitation of the University of Illinois to hold the meeting at Urbana was accepted. It was decided that the meeting would begin at 2:00 P.M. on Friday, February 18, 1910, and close Saturday afternoon, February 19. The Council planned for the program to consist of a business meeting, presentation of papers, address by the retiring president, and a symposium on "The Relation of Pure and Applied Science (A) to the Progress of Knowledge and to Practical Affairs, and (B) to Secondary Education." The symposium was to be participated in by five speakers chosen by the Council to present the subject from the point of view of the biologist, the chemist, and the physicist.

Isabel S. Smith, of Illinois College, Jacksonville, was appointed third member of the Publication Committee to succeed Dr. H. Foster Bain, elected at the last meeting of the Academy, who had resigned because of his removal to California.

The meeting of the Council was then adjourned.

REFERENCES

1. BAIN, H. FOSTER, The Initiation of the State Geological Survey. Illinois State Geological Survey Bulletin No. 60: 29-33, Urbana, 1931.
2. FORBES, S. A., History of the Former State Natural History Societies of Illinois. Transactions of the Illinois State Academy of Science I:18-30, 1908.
3. HIGLEY, WILLIAM KERR, Historical Sketch of the Academy. Special Publication Number 1 of the Chicago Academy of Sciences, Chicago, 1902.
4. HILDEBRAND, ELIZABETH, Head, General Reference Section, Peoria Public Library, Private Letter, April 5, 1949.
5. History of Jackson County, Illinois, with Illustrations etc.: 66-67, Philadelphia, 1878.
6. Prairie Farmer, May, 1853: 190-192.
7. ROLFE, C. W., Investigations Previous to the Founding of the Present State Geological Survey. Illinois State Geological Survey Bulletin No. 60: 23-26, Urbana, 1931.
8. Transactions of the Illinois State Academy of Science, Volume I, 1908.
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10. WHITENACK, ARTHUR E., Librarian, Reddick's Library, Ottawa, Illinois, Private Letter, March 18, 1949.

PROGRAM FOR THE 43rd ANNUAL MEETING
PAPERS PRESENTED

ARCHAEOLOGY AND ANTHROPOLOGY

C. C. BURFORD, *Chairman*
Urbana

1. More Data on Sites of the Peoria, Illinois, Region: Mrs. Ethel Schoenbeck, Peoria.
2. You Can Still Find More of Them: Dr. Dan Morse, Peoria.
3. The Illinois State Archaeological Society and Its Journal: Byron W. Knoblock, Quincy, President, Illinois State Archaeological Society.
4. Symposium, The Black Hawk War Area and Background: Irving W. Hurlbut, Davenport, Iowa, presiding.
   Speakers—John H. Hauberg, Rock Island; Irving W. Hurlbut, Davenport, Iowa; Russell Neuwerk, Moline; E. Lee Siemon, Rock Island.
5. Birdstones: Dr. T. Hugh Young, Nashville, Tenn.
6. Bannerstones: Ben Nussbaum, Fairbury, Illinois.
7. Pictures of Archaeology of Southern Illinois: Irwin Peithman, Southern Illinois University, Carbondale.

BOTANY

R. A. EVERS, *Chairman*
Illinois State Natural History Survey, Urbana

1. Albinism in Plants: Sister Mary Helen O'Hanlon, Rosary College, River Forest.
*2. The Ligneous Flora of Richland County, Illinois, by Robert Ridgway, an Unpublished Manuscript: George D. Fuller, Illinois State Museum and University of Chicago.
*3. The Carr and Daniels Collections of Fossil Plants from Mazon Creek: Wilson N. Stewart, University of Illinois, Urbana.
4. The Use of C^{14} in Plant Studies: Norbert J. Scully, Argonne National Laboratory, Chicago.
*5. Microscopic Anatomy of the Wood of Three Species of Junipers: Margaret Kaeiser, Southern Illinois University, Carbondale.
6. Absorption of Antibiotics by Natural Substrates: Paul Siminoff and David Gottlieb, University of Illinois, Urbana.
*7. Colchicine as a Mutagenic Agent for Streptomyces griseus: Erich Schuldt and David Gottlieb, University of Illinois, Urbana.
8. The Secondary Phloem of Heterangium americanum: John W. Hall, University of Illinois, Urbana.
9. Poisonous Plants of West-Central Illinois: R. Maurice Myers and T. Dee Seely. Senior author, Western Illinois State College, Macomb; junior author, High School, Patterson, Illinois.
*10. Plankton Counting Methods: Kenneth E. Damann, Eastern Illinois State College, Charleston.
*11. Utilization of Some Organic Acids by Streptomyces griseus for Streptomycin Production and Growth: C. V. Hubbard and H. H. Thornberry. Senior author.

* Published in this volume.

Rutgers University, New Brunswick, New Jersey; junior author, University of Illinois, Urbana.

12. Therapeutic Studies on Carnation Virus Diseases: Ralph W. Ames, University of Illinois, Urbana.

CHEMISTRY

F. O. GREEN, *Chairman*
Wheaton College, Wheaton

*1. Methoxyl Determination on Alkyl Esters of 2-Methoxybenzoic Acid: G. R. Yohe, Donald R. Hill, and Howard S. Clark, State Geological Survey, Urbana.
2. Preparation of Symmetrical N,N¹-Disubstituted Piperazines and Their Quaternary Ammonium Salts: D. R. Smith and R. L. Eifert, James Millikin University, Decatur.
3. Sodium in Our Present World: Elbert H. Hadley, Southern Illinois University, Carbondale.
4. Oxidation Potentials of Some Phenolic Compounds: F. P. Cassaretto and C. D. Lowry, Jr., Loyola University, Chicago.
5. The Use of Isotopes in Medicine: D. L. Tabern, Abbott Laboratories, Chicago.
*6. Kolbe Synthesis: G. W. Thiessen, Monmouth College, Monmouth.
7. Physical Methods in Paper Chromatography: Arthur A. Frost, Northwestern University, Evanston.
8. The Microbiological Assay of Vitamin B_{12} in Impure Solutions: Thomas J. Oliver, Abbott Laboratories, Chicago.
9. Coal Oxidation: Active Oxygen and the Russell Effect: G. R. Yohe, State Geological Survey, Urbana.

GEOGRAPHY

WILLIAM E. POWERS, *Chairman*
Northwestern University, Evanston

1. Europe's Climate Owes Much to Two Small Earth Features: W. O. Blanchard, University of Illinois, Urbana.
*2. Geographical Possibilities of Cork Production in the United States: Charles C. Yahr, Illinois State Normal University, Normal.
3. The Conservation of Coal for Metallurgical Coke: Walter H. Voskuil, Illinois State Geological Survey, Urbana.
4. Distribution of Beef Cattle in Florida: H. O. Lathrop, Illinois State Normal University, Normal.
*5. Water Resource Conservation in Illinois: H. E. Hudson, Illinois State Water Survey, Urbana.
*6. Slope Studies of Northern Illinois: Wesley Calef, University of Chicago, Chicago.
7. A Geographer's Concept of Conservation: Ernest E. Melvin, Northwestern University, Evanston.

GEOLOGY

H. B. WILLMAN, *Chairman*
Illinois State Geological Survey, Urbana

*1. Student Projects: an Experiment in Geologic Education: F. M. Fryxell, Augustana College, Rock Island.

* Published in this volume.

*2. Some Easily Constructed Models for Teaching Optical Mineralogy: Carleton A. Chapman, University of Illinois, Urbana.
*3. Atomic Models of the Silicates as an Essential Aid in the Teaching of Mineralogy: Donald M. Henderson, University of Illinois, Urbana.
*4. Glacial Lake Merrimac: J Harlen Bretz, University of Chicago, Chicago.
5. Evidence of the Extension of the Labradorean Ice Sheet into Eastern Iowa, Tazewell-Wisconsin Substage: Morris M. Leighton, Illinois State Geological Survey, and Paul R. Shaffer, University of Illinois, Urbana.
*6. Current Evaluation of the Cambrian-Keweenawan Problem: Gilbert O. Raasch, Illinois State Geological Survey, Urbana.
*7. The Mt. Simon Sandstone in Northern Illinois: J. S. Templeton, Illinois State Geological Survey, Urbana.
8. Geological Control of Exploratory Drilling: George M. Wilson, Illinois State Geological Survey, Urbana.
9. A Type of Boghead Coal in Illinois: R. M. Kosanke, Illinois State Geological Survey, Urbana.
*10. Petrology of the Lower Burlington Limestone in Western Illinois: Donald L. Graf, Illinois State Geological Survey, Urbana.
*11. Metamorphic Development of the Crawford Notch Quadrangle, New Hampshire: Donald M. Henderson, University of Illinois, Urbana.
*†12. Preglacial Gravels in Henry County, Illinois: Leland Horberg, University of Chicago, Chicago.

PHYSICS

CLARENCE R. SMITH, *Chairman*
Aurora College, Aurora

1. A Study of Inductive Circuits: Herbert A. Johnson, Augustana College, Rock Island.
2. The Special Theory of Relativity and Electromagnetic Induction: W. J. Hooper, Principia College, Elsah.
*3. Survey of City Noise: G. L. Bonvallet, Armour Research Foundation of Illinois Institute of Technology, Chicago.
4. Report of the New York, February, Annual Meeting of the American Association of Physics Teachers: Lester I. Bockstahler, Northwestern University, Evanston.
5. Projection of Polarization Phenomena: D. L. Eaton, Northern Illinois State Teachers College, DeKalb.
6. A New Instrument for Fluorimetry: Harris M. Sullivan, Central Scientific Company, Chicago.
*7. Spectral Characteristics of Flash Discharges: W. S. Huxford and H. N. Olsen, Northwestern University, Evanston.
*8. Photographic and Optical Techniques Useful in the Small-School Laboratory: Howard C. Roberts, University of Illinois, Urbana.
9. The Use of Radioactive Materials in the Undergraduate Laboratory: O. L. Railsback, Eastern Illinois State College, Charleston.
10. Measuring the Solar Constant and Studying Its Influence Upon the Earth's Climate: Albert M. Pezzuto, New Table Mountain Solar Observatory of the Smithsonian Institution, Wrightwood, California.
11. Magnetic Support for Obtaining High Centrifugal Fields: William H. Lucke, Southern Illinois University, Carbondale.

† This paper was presented at the meeting, but was not listed on the printed program.
* Published in this volume.

PSYCHOLOGY AND EDUCATION

R. WILL BURNETT, *Chairman*
Urbana

1. A Digest of Significant Papers Presented at the Annual Meeting of the National Association for Research in Science Teaching: N. E. Bingham, Northwestern University, Evanston.
2. Earth Science as a Prerequisite for the Teaching of Geography: Ben H. Wilson, Joliet Township High School and Junior College, Joliet.
3. Findings from a Common Learnings Course Involving Science: Mrs. Audrey Lindsey, University High School, University of Illinois, Urbana.
4. Experiences in Educating for Human Relations: Mrs. Ruth Franham Osborne, Hinsdale Township High School, Hinsdale.
*5. Validation by Means of the Sociogram of a Technique for Promoting Social Acceptability in Elementary School Children: Elva E. Kinney, Greenville College, Greenville.
6. Meeting Students' Needs: Charlotte L. Grant, Oak Park and River Forest High School.
*7. A Study of College Science Courses Designed for General Education: Robert A. Bullington, MacMurray College, Jacksonville.
8. Some Findings of a Study of Competencies Required in Successful Teaching of Science in the Schools of Illinois: T. A. Nelson, Lyons Township High School, LaGrange.
9. Experience in Program Modifications in Science: Nelson L. Lowry, Arlington Heights Township High School, Arlington Heights.
10. Findings from the "Holding Power" Study of the Illinois Secondary School Curriculum Project: Kenneth B. Henderson, University of Illinois, Urbana.
11. Educating Teachers Concerning Scientific Features of the Community: D. Elton Nelson, Hinsdale Township High School, Hinsdale.
12. The National Aviation Education Classroom Demonstration Project: Horace S. Gilbert, Civil Aeronautics Administration.
13. Science and Philosophy in General Education Programs: John H. Woodburn, Illinois Normal University, Normal.

SOCIAL SCIENCE

LEWIS MAVERICK, *Chairman*
Southern Illinois University, Carbondale

EMPHASIS ON SOCIOLOGY

*1. Sociological Problems in the Study of Industrial Relations: Donald E. Wray, University of Illinois, Urbana.
2. The Swedish Theatre of Chicago and Its Social Background: Henriette Naeseth, Augustana College, Rock Island.
3. What Is So Human About Ants and Termites? George K. Plochmann, Southern Illinois University, Carbondale.
*4. Recent Studies of the Relative Power of Nature and Nurture, Monozygotic Twins: Grace M. Jaffe, Barat College, Lake Forest.
5. The Social Studies for Future Teachers—A Functional Major: Fritiof O. Ander, Augustana College, Rock Island.

* Published in this volume.

EMPHASIS ON GOVERNMENT AND ECONOMICS

1. The Administration of the Federal Airport Act: George B. Rea, Northwestern University, Evanston.
2. Supply and Demand for Pig Iron in the United States, 1904 to 1948: Lewis A. Maverick, Southern Illinois University, Carbondale.
3. Problems of Constitutional Revision in Illinois and Iowa: Stanley Erikson, Augustana College, Rock Island.
4. The Attitude of *The Chicago Tribune* Toward American Foreign Policy, 1939 to December 7, 1941: Marcus William Kulyan, Northwestern University, Evanston.
5. The Interdependence of the Social and Natural Sciences: G. Carl Wiegand, Loyola University, Chicago.
6. Beef Cattle Industry in Illinois, 1840-50: C. Clyde Jones, Northwestern University, Evanston.
*7. The Need for Corporate Research in the Social Sciences: J. K. Johnson, Southern Illinois University, Carbondale.

ZOOLOGY

CHARLES J. WIDEMAN, *Chairman*
Loyola University, Chicago

1. Etymological Problems in Herpetological Nomenclature: Albert G. Smith, Loyola University, Chicago.
*2. The Use of Horse Strongyle Larvae in Screening Compounds for Anthelmintic Activity: Norman D. Levine, University of Illinois, Urbana.
*3. Comparative Studies of Normal and Piebald Hamsters: Charles L. Foote and Florence M. Foote, Southern Illinois University, Carbondale.
4. Studies of Ciliates 1—The Encystment and State of Depression in Oxytrichidae: Dimitri Sokoloff, Mundelein College, Chicago.
*5. Field Notes on the Squash Bug, Anasa tristis (De Geer): W. V. Balduf, University of Illinois, Urbana.
*6. Ecological Notes on Silpha americana: E. J. Long, Quincy College, Quincy.
7. Our Food, Our Health, and Our Future: A. J. Carlson, University of Chicago, Chicago.
*8. An Investigation of the Occurrence of Enterobius vermicularis Ova in Dust from Homes and Public Buildings: Wayne W. Wantland, Mildred M. Carmichael, Clifford Storm, Mary Ho, Illinois Wesleyan University, Bloomington.
9. Cysticercus fasciolaris in the Wild Rat: Wayne W. Wantland, Kenneth E. Dye, Harold M. Kemple, Illinois Wesleyan University, Bloomington.
*10. A Study of the Incidence of Endamoeba gingivalis in a Central Illinois Community: Wayne W. Wantland, Hubert Engel, Seije Nakada, Illinois Wesleyan University, Bloomington.
11. Hunger Activity in Decerebrate Pigeon: William Sangster, University of Illinois (Navy Pier), Chicago.
12. Animal Succession in Temporary Ponds: John D. Parsons, Southern Illinois University, Carbondale.
*13. A New Method for Staining Cells with Cobalt and Bal: Theodore N. Tahmisian, Argonne National Laboratory, Chicago.
14. The Relationship of the Resting Potential of the Frog Eye to the Blood Sugar Level: Allyn E. Gilbert, University of Illinois, Urbana.

* Published in this volume.

COLLEGIATE SECTION

HARRY J. FULLER, *Coordinator*
University of Illinois, Urbana

JANE MARTIN, *Chairman*
Monmouth College, Monmouth

1. An Alternative Separation of Copper and Cadmium Ions in Qualitative Inorganic Analysis: Ralph Medhurst, Monmouth College, Monmouth.
2. The Preparation and Purification of 3, 4-Dibromotoluene and Their Reaction with One Mole of Magnesium in the Grignard Reagent: John R. Dyer, Northwestern University, Evanston.
3. Studies on Acephaline Gregarines of Lumbricus Terrestris: Thomas C. Hartney, Loyola University, Chicago.
4. Automorphisms of a Cyclic Group: Virginia Tyler, Rockford College, Rockford.
5. Refractive Index versus Concentration Curves for Aluminum and Magnesium, Chloride and Bromide: James L. Baldwin, Eastern Illinois State College, Charleston.
6. Size and Pattern Variations in Plethodon cinereus from the Indiana Dunes: Edward Kos, Loyola University, Chicago.
7. Iodine Inhibition of Photochemical Reactions: Robert Martin, Northwestern University, Evanston.
8. The Preparation of Some Dialkyl Hydroquinones: John Cessna, Augustana College, Rock Island.
9. Antobiotics as Bacteriostatic Agents for the Cultivation of Cestodes in Vitro: Janet Boles, Monmouth College, Monmouth.
10. Location of Colorless Compounds on a Resolved Chromatogram: Peter Lykos, Northwestern University, Evanston.
11. Study of Cicatrization in Plant Tissues: Dolores Bresingham, Mundelein College, Chicago.
12. Comparative Study of the Structure of the Nuclei of Some Volvocales: Marilyn Tucker, Mundelein College, Chicago.
13. Student Chemistry Research Program at Mundelein College: Joan Haninger, Mundelein College, Chicago.
14. Observations on the Effect of Magnesium Ion in the Blood of the Golden Hamster: Edward Shinn, Quincy College, Quincy.
15. Botanical Survey of the Campus of Western Illinois State College: Norman C. Place, Western Illinois State College, Macomb.
16. Separation of Crystalline Materials from Burdock and Plantain by Chromatography and Tests for Their Antibacterial Properties: Celine Paul and Lorraine Sporar, College of St. Francis, Joliet.

* Published in this volume.

BOTANY

THE LIGNEOUS FLORA OF RICHLAND COUNTY, ILL., BY ROBERT RIDGWAY

(AN UNPUBLISHED MANUSCRIPT)

GEORGE D. FULLER
Illinois State Museum and
The University of Chicago

When the home of the late Robert Ridgway, known as "Bird Haven," at Olney, Illinois, passed into the control of the Departments of Botany and Zoology of the University of Chicago and became a Nature Sanctuary, portions of the library of this distinguished scientist were stored in the Botany Building of the University of Chicago. Among other old manuscripts there was found one having the above title, and upon examination it was found to have been written by Mr. Ridgway during the last years of his life and for which he had not succeeded in finding a publisher.

In 1927, an abstract of this manuscript was presented at a meeting of the Illinois State Academy held at Joliet (Ridgway, R., The ligneous flora of Richland Co., Ill., Trans. Ill. State Acad. Sci. 20: 105-115, 1928) but the unpublished portions of the article contained so many details concerning the distribution of the different plant species in the county that it seemed important to preserve these details for the students of the flora of Illinois. There were three typewritten copies of the manuscript, in different stages of revision, and it seemed wise to deposit the three copies where they could be examined by botanists interested in the flora of Illinois. The institutions that were selected as the depositories of the manuscripts were the Illinois State Museum, Springfield; the Herbarium of the Department of Botany, the University of Illinois, Urbana; and the Chicago Natural History Museum, Chicago.

The best of the manuscripts, the only one with plates of photos of trees, has been accepted by the Director of the Illinois State Museum who has had it bound and placed in the library of the Museum. It contains 133 typewritten pages and 43 plates (photographs). It has many handwritten notes by the author and it contains copies of letters concerning Mr. Ridgway's correspondence in his efforts to get a publisher.

The other copies have been accepted by the curators of the herbaria of the University of Illinois and of the Chicago Natural History Museum and have been placed on file where they may be consulted by interested botanists.

REPORT ON THE CARR AND DANIELS COLLECTIONS OF FOSSIL PLANTS FROM MAZON CREEK

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The Natural History Museum of the University of Illinois[1] has had since 1920, two collections of fossil plants made up almost entirely of specimens from the now famous Mazon Creek area near Morris, Illinois. The collectors, L. E. Daniels and J. C. Carr, both resided in Morris, Illinois, when making their respective collections.

From the time these collections were procured by the University, the majority of the specimens remained in storage and for the most part inaccessible for study. At one time, part of the Daniels collection was investigated by A. C. Noé (1925) who published photographs of several specimens.

In order to make the material in the Carr and Daniels collections available for further study all specimens which were well enough preserved were identified and catalogued. The identification of specimens was done by comparing them with those previously figured and described by Zeiller (1888), White (1899), Noé (1925), Hirmer (1927), Bell (1938, 1944), and Janssen (1939, 1941). The generic and specific names were checked with those listed by Jongmans (1913-37).

The first extensive studies of the fossil flora of the Mazon Creek locality were by Lesquereux (1866, 1870). The results of his studies were later incorporated in a comprehensive account of the fossil plants of the American Carboniferous (1879, 1880). In a series of brief reports, White, while a member of the Illinois State Geological Survey, mentioned the occurrence of several genera of fossil plants from Mazon Creek. His observations on the fossil flora of the Pennsylvanian of Illinois resulted in the subdivision of this system into the Pottsville, Carbondale, and McLeansboro groups. Lesquereux's nomenclature (1866, 1870, 1879, 1880) was revised by Noé (1925), with more recent revisions of the fossil flora of Northern Illinois by Janssen (1939, 1941).

The Collections

The majority of the specimens are ironstone concretions with only a few compressions on shale and stem casts. Geographically, the Mazon Creek fossils are still to be found along the so-called Ox Bow of the Mazon River, 6 to 6¾ miles southeast of Morris extending from NE. ¼ sec. 24 to NE. ¼ sec. 25, T. 32 N., R. 7 E. Stratigraphically the concretions, when found in place, lie in the Francis Creek shale just above No. 2 coal of the Lower Carbondale group.

Because of the fragmentary nature of fossil plant remains the problems of their nomenclature and classification are more difficult than for living plants, where complete specimens are available. For this reason paleobotanists are primarily in-

[1] The author wishes to thank Professor D. F. Hoffmeister, Curator of the Natural History Museum, for making the Carr and Daniels collections available for study.

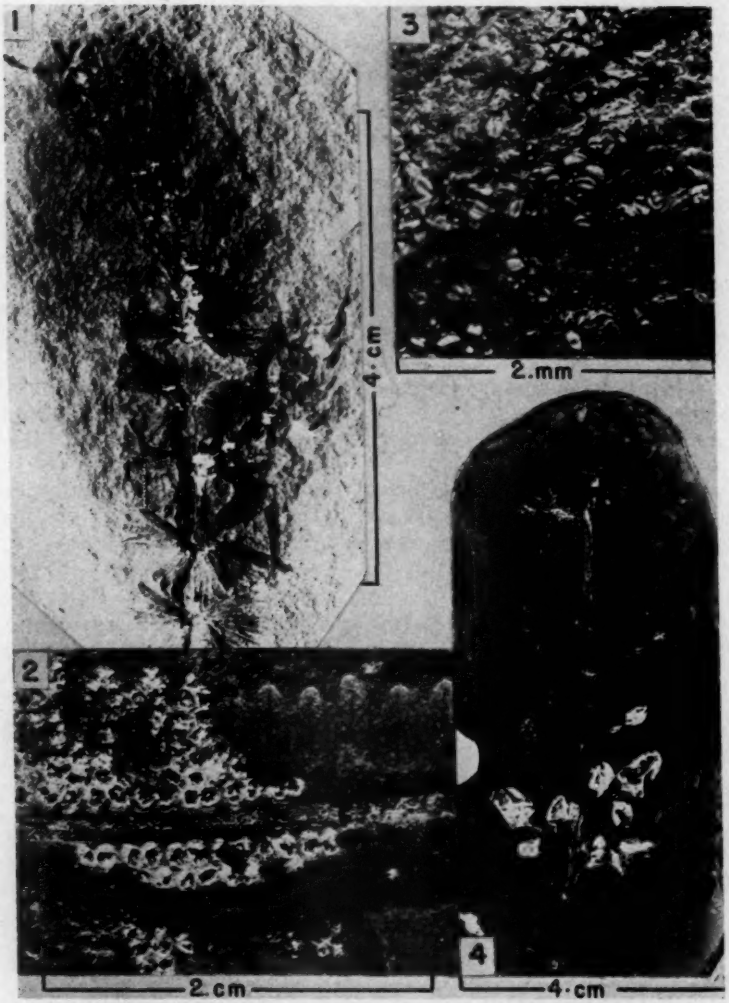

FIG. 1.—Cone-bearing branch of *Sphenophyllum cuneifolium.*

FIG. 2.—Pinna of *Pecopteris* (*Ptychocorpus*) *unita* showing fertile and sterile aspect of a pinnule.

FIG. 3.—Monolete spores of *Codonotheca caduca* in the matrix of a concretion.

FIG. 4.—Pinna of *Crossotheca sagittata* with fertile pinnules intercalary in position.

terested in those specimens which bear reproductive parts and thus indicate something of the natural affinities of the fossil plants. In the Carr and Daniels collections there are many fertile specimens of lycopsids, sphenopsids, and pteropsids. Figures 1-4 show some of the fructifications (see explanation of figures for more complete descriptions) which still contain spores within their sporangia (fig. 3). As is true of all fossil plant remains collected from the Mazon Creek locality, the majority is sterile leaf material of the genera Pecopteris and Neuropteris. Many of these sterile leaf fragments are large enough to show something of the high degree of polymorphism within a frond. A critical examination of this material, not undertaken here, may show that a number of species currently recognized as distinct can be grouped in only a few species.

Of the total number of specimens (4018) in the two collections, 758 belong to the Daniels collection and 3260 to the Carr collection. The combined collections have 103 different species belonging to 51 genera.

List of Genera and Species

(Number of specimens in Carr and Daniels Collections given in parenthesis)

Phylum—*Tracheophyta*
Subphylum—*Lycopsida*
Order—*Lepidodendrales*
Genera and species:
Bothrodendron sp? Lindley and Hutton (1)
Halonia sp? Lindley and Hutton (1)
Knorria sp? Sternberg (1)
Lepidodendron Sternberg (9)
L. aculeatum Sternberg (9)
L. dichotomum Sternberg (1)
L. lanceolatum Lesquereux (4)
L. obovatum Sternberg (25)
L. rigens Lesquereux (5)
L. rimosum Sternberg (2)
L. veltheimi Sternberg (3)
L. wortheni Lesquereux (3)
Lepidophloios sp? Sternberg (5)
L. acerosus Kidston (3)
L. luricinus Sternberg (2)
L. protuberans Lesquereux (1)
Lepidophyllum longifolium Brongniart (5)
Lepidostrobophyllum sp? Hirmer[2] (1)
L. brevifolium (Lesquereux) Hirmer (1)
L. intermedium (Lindley and Hutton) Hirmer (3)
L. lanceolatum (Lindley and Hutton) Hirmer (2)
L. lancifolium (Brongniart) (26)
L. majus (Brongniart) Hirmer (12)
L. ovatifolium (Lesquereux) Hirmer (45)
L. triangulare (Zeiller) Hirmer (7)
Lepidestrobus sp? Brongniart (3)
L. brevifolium Lesquereux (16)
L. brownii ? Schimper (1)
L. hastatus Lesquereux (3)
L. lancifolium Lesquereux (1)
L. oblongifolium Lesquereux (6)
L. triangularis Zeiller (2)
Sigillaria sp? Brongniart (2)
Stigmaria ficoides (Sternberg) Brongniart (10)
Syringodendron sp? Sternberg (4)
Order—*Lycopodiales*
Genus and species:
Lycopodites meeki Lesquereux (16)
Subphylum—*Sphenopsida*
Order—*Sphenophyllales*
Genera and species:
Sphenophyllum cuneifolium[3] Sternberg (1)
S. emarginatum (Brongniart) Koenig (18)
S. longifolium Germar (2)
S. majus (Bronn) Bronn (1)
Order—*Equisetales*
Genera and species:
Annularia sp? Sternberg (8)
A. radiata (Brongniart) Sternberg (127)
A. sphenophylloides (Zenker) Gutbier (32)
A. stellata (Schlotheim) Wood (88)
Asterophyllites sp? Brongniart (57)
A. equisetiformis Schlotheim (13)
A. longifolius (Sternberg) Brongniart (7)
Calamites sp? Schlotheim (16)
C ramosus Artis (2)
C. suckowi Brongniart (6)
Calamostachys sp? Schimper (8)
C. germanica Weiss (1)
C. magna Lesquereux (1)
C. solmsi (Weiss) Weiss (2)
Macrostachya sp? Schimper (2)

[2] Lepidostrobophyllum. Hirmer, M. 1927—Handbuch der Palaobotanik, Munchen und Berlin; 231. This genus, though a useful one, does not meet the requirements of valid publication according to the International Rules.

[3] This specimen bears two cones. (See fig. 1.)

M. infundibuliformis (Brongniart) Schimper (1)
Pinnularia Lindley and Hutton (4)
Subphylum—Pteropsida
Orders[4]—*Filicales* and *Cycadofilicales*
Genera and species:
Acitheca polymorpha (Brongniart) Schimper (4)
Alethopteris sp? Sternberg (2)
A. ambigua Lesquereux (10)
A. grandini (Brongniart) Goeppert (3)
A. lonchitica (Schlotheim) Unger (3)
A. serli (Brongniart) Goeppert (43)
Alloiopteris sp? Potonié (1)
Aphlebia sp? Presl (66)
Callipteridium sullivanti (Lesquereux) Weiss (17)
Carpolithes sp? Sternberg (4)
Caulopteris sp? Lindley and Hutton (16)
Codonotheca caduca Sellards (27)
Crossotheca sagittata (Lesquereux) Zeiller (63)
Cyclopteris sp? Brongniart (105)
Dactylotheca sp? *Zeiller* (2)
Diplothmema furcatum (Brongniart) Stur (5)
Eremopteris missouriensis Lesquereux (1)
Holcospermum sp? Nathorst (7)
Lagenospermum sp? Nathorst (1)
Linopteris muensteri (Eichwald) Potonié (4)
L. neuropteroides (Gutbier) Potonié (2)
Mariopteris sp? Zeiller (4)
M. decipiens ? Lesquereux (3)
M. mazoniana (Lesquereux) White (1)
M. muricata (Schlotheim) Zeiller (6)
M. muricata var. *nervosa* (Schlotheim) Zeiller (5)
M. sphenopteroides (Lesquereux) White (11)
Mixoneura sp? Weiss (2)
M. ovata (Hoffman) Weiss (10)
Neuropteris sp? Brongniart (23)
N. clarksoni Lesquereux (20)
N. crenulata ? Brongniart (2)
N. fimbriata Lesquereux (1)
N. flexuosa Sternberg (26)
N. gigantea Sternberg (8)
N. heterophylla Brongniart (14)
N. missouriensis Lesquereux (3)
N. rarinervis Bunbury (32)
N. scheuchzeri Hoffman (898)
N. tenuifolia (Schlotheim) Sternberg (26)
N. plicata Sternberg (9)
Odontopteris sp? Brongniart (17)
O. aequalis Lesquereux (8)
O. brardleyi ? Lesquereux (1)
O. schlotheimi Brongniart (2)
O. subcuneata Bunbury (5)
O. wortheni Lesquereux (8)
Oligocarpia sp? Geoppert (1)
Pachytesta sp? Brongniart (3)
Pecopteris sp? Brongniart (24)
P. (Asterotheca) abbreviata Brongniart (53)
P. (Asterotheca) arborescens (Brongniart) Sternberg (214)
P. (Asterotheca) candolleana Brongniart (3)
P. cisti Brongniart (7)
P. clintoni Lesquereux (7)
P. (Asterotheca) crenulata Brongniart (13)
P. (Asterotheca) hemitelioides Brongniart (4)
P. (Asterotheca) miltoni (Artis) Brongniart (651)
P. obliqua Brongniart (5)
P. (Asterotheca) oreopterida Schlotheim (26)
P. (Senftenbergia) pennaeformis (Brongniart) Sternberg (3)
P. (Dicksonites) pluckeneti (Schlotheim) Brongniart (59)
P. (Dactylotheca) plumosa (Artis) Brongniart (6)
P. pseudovestita White (22)
P. (Asterotheca) serpillifolia Lesquereux (33)
P. (Asterotheca) squamosa Lesquereux (19)
P. (Dactylotheca) sturi ? Sterzel (1)
P. (Ptychocarpus) unita Brongniart (545)
Schopfia sp? Janssen (1)
Sphenopteris sp? Brongniart (11)
S. artemisaefoloides Crépin (23)
S. (Oligocarpia) brongniarti (Zeiller) Stur (2)
S. (Renaultia) chaerophylloides (Brongniart) Presl (16)
S. (Renaultia) gracilis (Brongniart) Presl (6)
S. mixta Schimper (2)
S. obtusiloba Brongniart (6)
S. spiniformis Kidston (4)
S. subcrenulata ? Lesquereux (1)
Spiropteris sp? Schimper (13)
Sporangites accuminata ? Dawson (1)
Trigonocarpus sp? Brongniart (10)

Order—*Cordaitales*
Cordaianthus sp? Grand Eury (9)
Cordaicarpus sp? Geinitz (1)
Cordaites grandifolius Lesquereux (2)
Undetermined specimens (61)

[4] It has long been suspected that many of the homosporus fructifications borne on fern-like leaves and now assigned to the Filicales may, in reality, be the microsporangia of heterosporous members of the Cycadofilicales. Furthermore, there are many species with fern-like foliage, now assigned to artificial (form) genera, the reproductive structures of which are unknown. For these reasons it is impossible, in most cases, to assign a species with any degree of certainty to either the Filicales or Cycadofilicales. Thus, it is necessary to group these two orders.

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MICROSCOPIC ANATOMY OF THE WOOD OF THREE SPECIES OF JUNIPERS

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An attempt has been made to seek criteria for separating three American species of junipers on the basis of the microscopic structure of their wood. Peirce (4) has a key to genera of the Cupressaceae. Phillips (5) has described the microscopic wood anatomy of certain members of the genus *Juniperus* and has separated *J. virginiana* L. and *J. lucayana* Britt. from *J. procera* Hochst. (an East African form) on the basis of thin horizontal walls in the ray cells in the last named species (figs. 1, 5). *J. virginiana* L. and *J. lucayana* Britt. both were noted to have nodular thickenings on the vertical end walls of the ray cells (as shown for *J. monosperma* (Engelm.) Sarg., fig. 4), and in this respect are unlike any other species of conifer that he reported except *Libocedrus decurrens* Torr. *J. virginiana* L. is then separated from *L. decurrens* Torr. on the basis of the presence, in the former species, of intercellular spaces at the corners of the tracheids as observed in traverse section (fig. 7). He noted also that the cross-field pits are generally larger and are more regularly arranged in *J. virginiana* L. and *J. lucayana* Britt. than in *Libocedrus.*

Phillips also lists abundant wood parenchyma (relatively abundant for conifers), the presence of nodular thickenings on the transverse walls of parenchyma cells (fig. 6), and the cupressoid cross-field pits (fig. 4, 5, 6, 10) as characters serving to delimit the three junipers he reported from most other conifer woods. All three species reported by him have the typical "cedar-like" odor of pencils.

The writer has used *J. virginiana* L.; *J. Ashei* Buchh.; young (3-5 year old) twigs of hybrids of *J. virginiana* L. X *J. Ashei* Buchh.; *J. monosperma* (Engelm.) Sarg.; and *J. procera* Hochst. for comparative purposes. Wood samples were prepared in the usual manner (6) and sections were cut 20-30 microns thick. Macerated wood was prepared in Jeffrey's Solution.

Acknowledgment is made to the following people for assistance in providing materials: To Dr. B. Francis Kukachka, U. S. Forest Products Laboratory, Madison, Wisconsin, for *J. virginiana* L., from Linn, Florida; *J. Ashei* Buchh., from Austin, Texas; and *J. monosperma* (Engelm.) Sarg., from Arizona. Dr. Marion T. Hall, Henry Shaw School of Botany, Washington University, St. Louis, provided the hybrid *J. virginiana* L. X *J. Ashei* Buchh. which was collected on McVey Knob in Ozark County, Missouri, the most eastern known distribution of *J. Ashei* Buchh. Mr. Milton Scott of Miami, Florida, furnished the *J. procera* Hochst., from the U. S. Plant Introduction Garden. The *Metasequoia glyptostroboides* Hu and Cheng wood specimen was collected by Dr. Ralph W. Chaney from the Hupeh Province of China

and presented to Mr. O. A. Oakes of Wilmette, Illinois, from whom the writer procured a sample. It is used to illustrate the taxodioid type of cross-field pitting, as is also the *Podocarpus Comptonii* Buchh. that was collected by Dr. John T. Buchholz on Mt. Mou, New Caledonia (figs. 11, 12).

Local collections provided material for *Pinus sp.* and *Picea polita* (Sieb. and Zucc.) Carr. Figure 8 shows the large window-like pit found in certain of the pines, besides small pits of the pinoid type. Figure 9 shows the piceoid type of cross-field pit.

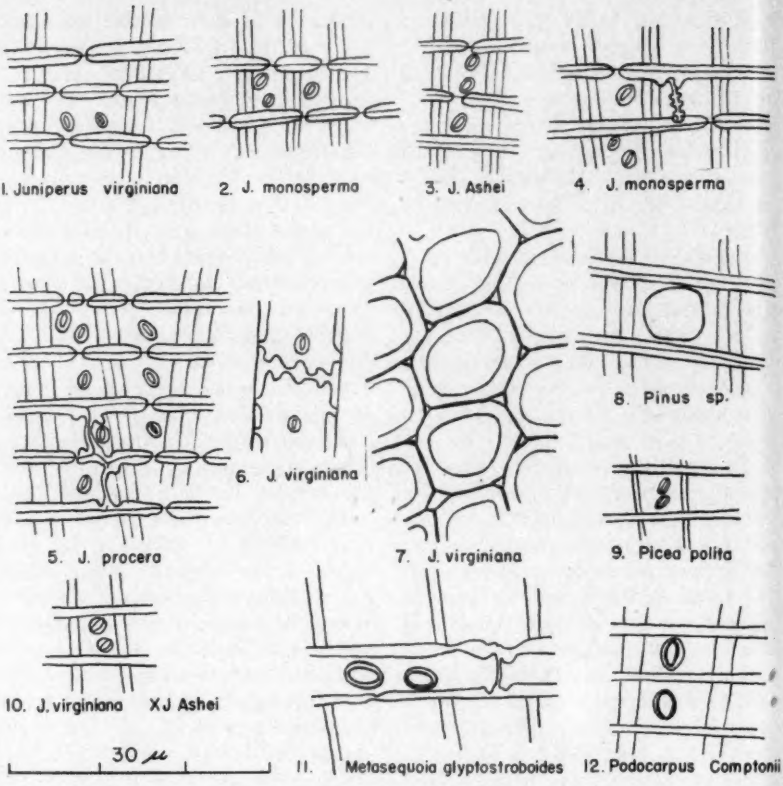
Table 1 summarizes the data for the species analyzed (1). The tracheid study from early wood disclosed the "very thin" wall character. The size of cross-field pit apertures, on a basis of ten random measurements, showed somewhat smaller sizes, on the average, in *J. Ashei* Buchh. and *J. monosperma* (Engelm.) Sarg. than in *J. virginiana* L. or *J. procera* Hochst. All were of the cupressoid type, although there have been reported occasional ones of the taxodioid type (5) (figs. 11, 12). Small tangential bordered pits were noted in all species though only rarely. Tangential pits are rare in early (spring) wood of conifers (3).

Tracheid length measurements from random counts of macerated wood were made of 100 tracheids for each species. The table gives means with their standard errors and standard deviations with their standard errors. Statistical treatment to measure the significance of the difference between means (2) i.e., the square root of the sum of the squares of the two standard errors of the means, was undertaken to compare the species with one another. This root is the standard error of the difference between the two means. In every case the difference between the means exceeded twice the root and is, therefore, to be regarded as significant. The hybrid was treated similarly and again showed significant difference from the parent types, as well as the other two species. However, the samples were of young wood only, the foliage of which was more like *J. Ashei* Buchh. than *J. virginiana* L. Further work is needed on mature wood. Tracheid length was greatest in *J. virginiana* L., with *J. Ashei* Buchh. and *J. monosperma* (Engelm.) Sarg. in descending order. There was less difference in tracheid length between the last two named species than when compared to *J. virginiana* L. Although *J. virginiana* L. and *J. Ashei* Buchh. hybridize easily, *J. virginiana* L. belongs to the polyspermous complex whereas *J. Ashei* Buchh. and *J. monosperma* (Engelm.) Sarg. both belong to the monospermous complex.

Intercellular spaces between tracheids were present in all species (fig. 7).

Except for *J. procera* Hochst. (fig. 5) the horizontal walls of the ray parenchyma are as thick, or nearly as thick, as the tracheid walls in early wood cross-field views (figs. 1, 2, 3, 4, 6). The end walls are nodular in all species except *J. procera* Hochst. (figs. 4, 5). Primary pit-fields occur in the horizontal walls of all species studied (figs. 1, 2, 3, 4, 5), and indentures are also consistently present (figs. 4, 5).

Xylem parenchyma is more abundant than five cells per square millimeter under magnification of X50 or more and is indicated as "Abundant for Conifers" for all species (5). It is present in all forms re-



FIGURES 1 TO 12

1. From radial section of wood showing cross-field pits of *Juniperus virginiana* L. of cupressoid type; primary pitfields in horizontal walls of ray parenchyma cells.
2. Same for *J. monosperma* (Engelm.) Sarg.
3. Same for *J. Ashei* Buchh.
4. Same for *J. monosperma* (Engelm.) Sarg.; also showing nodular walls of ray parenchyma cells and indentures.
5. From radial section of wood of *J. procera* Hochst. showing smooth end walls of ray parenchyma cells and indentures.
6. From tangential view of wood parenchyma cells of *J. virginiana* L. showing nodules on transverse walls and primary pitfields on vertical walls.
7. From transverse section of early wood of *J. virginiana* L. showing intercellular spaces.
8. From radial section of early wood of *Pinus sp.* to show large window-like or primary pitfield.
9. From radial section of early wood of *Picea polita* (Sieb. and Zucc.) Carr. to show piceoid type of cross-field pits.
10. From radial section of early wood of *J. virginiana* L. X *J. Ashei* Buchh. to show cupressoid type of cross-field pits.
11. From radial section of early wood of *Metasequoia glyptostroboides* Hu and Cheng to show taxodioid type of cross-field pits.
12. From radial section of early wood of *Podocarpus Comptonii* Buchh. to show taxodioid type of cross-field pits.

MICROSCOPIC STRUCTURE OF JUNIPER WOOD

TABLE 1.—SUMMARY OF DATA OF WOOD STRUCTURE

	General					Tracheids—Early Wood								Rays				Parenchyma		
							Tracheid Length (Radial Sections)							(Radial)			(Tang.)			
	Young (Y) Mature (M)	G. Rings Indistinct	Hrwd. Colored	Odor	Geog. Reg.	Wall Thickness Microns	Lumen Width Microns	Ratio	Cross-Field Pits Cupressoid	Pit Aperture Range Microns	Pit Aperture Ave. Microns	No. of Counts	Range mm	Most Freq. Range mm	Mean	Standard Deviation	Intercellular Spaces (X-sec.)	Horizontal Walls Thin	Horizontal Walls "Pitted"	End Walls Nodular	Indentures	(50 H.P. Fields X440) Total No. Ray Cells	Range—Cells/Ray	Most Frequent Range	Present	"Abundant"	End-Walls Nodular
Juniperus virginiana L.	M		+	+	N. A.	3.0	27.0	1:9.0	+	6.0	6.0	100	1.58—4.10	2.55—2.94	2.70±.038	.680±.041	+		+	+	+	276	1-14	5	+	+	+
J. Ashei Buchh.	M		+	+	N. A.	5.1	27.0	1:5.2	+	4.5-6.0	4.8	100	1.38—2.63	1.80—1.99	1.94±.031	.310±.021	+		+	+	+	494	1-7	2	+	+	+
J. monosperma (Engelm.) Sarg.	M		+	+	N. A.	3.0	19.5	1:6.5	+	3.0-3.7	3.3	100	.65—2.22	1.25—1.94	1.49±.038	.380±.026	+		+	+	+	480	1-15	2	+	+	+
J. virginiana X *J. Ashei*	Y	?	+	+	N. A.	4.9	20.1	1:4.1	+	4.5-6.0	4.8	100	.51—1.45	.85—1.04	.89±.021	.214±.015	+		+	+	+	121	1-5	2	+	+	+
J. procera Hochst.	M	+	+	+	Afr.	3.0	15.6	1:5.2	+	6.0	6.0	100	.78—2.99	2.25—2.44	1.97±.043	.438±.031	+	+	+	+		168	1-6	3	+	+	+

ported. Primary pit-fields were noted in the vertical walls, and transverse (end) walls were nodular in all species as observed in tangential sections (fig. 6). No consistent zonation was noted although tendencies from sporadic to a type of zonation about midway in early (spring) wood were observed in transverse sections. Many more samples need to be studied, however, before this feature or the variants observed could be safely applied.

Counts were also made of the number of cells in the uniseriate rays as observed in tangential sections. Fifty microscopic field counts at X440 were made for each species. The most frequent range was five cells in height for *J. virginiana* L., three for *J. procera* Hochst., and two for all the others. The total number of wood ray cells was higher for *J. Ashei* Buchh. and *J. monosperma* (Engelm.) Sarg. than for *J. virginiana* L. The hybrid young wood showed the lowest total number of ray cells.

The data presented in table 1 on tracheid length and on ray height in number of cells would appear to support further the criteria used for specific taxonomic differences among the forms listed.

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COLCHICINE AS A MUTAGENIC AGENT FOR *STREPTOMYCES GRISEUS*

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Several investigators have caused mutations in morphology and in the ability of *Streptomyces griseus* to produce streptomycin with X-rays or ultra-violet light, Waksman and Harris (Proc. Soc. Exptl. Biol. Med. 71: 232, 1949), Appleby (J. Gen. Microbiol. 2: 80, 1948), but use of colchicine as a mutagenic agent has not been reported. Colchicine is a well known agent for producing chromosomal variations in higher plants and might increase either the metabolic functions of the Actinomycetes or produce other aberrations. The culture of *Streptomyces griseus* used for these studies had been maintained in our laboratory several years and showed no propensity for spontaneous variation. Sterile stock solutions of colchicine in distilled water were kept at 4°C in the dark to prevent oxidation to the inactive aldehyde and were used within three weeks. All studies were carried out using concentrations of colchicine ranging from 0.001 to 5.0 percent.

Colchicine was toxic to *S. griseus* as shown by the inhibition or abnormal germination of spores in broth containing the reagent. There is a rough, inverse relationship between the concentration of colchicine and the length of the germ tube or the amount of secondary branching. Washed spores were suspended in broth solutions of colchicine and allowed to germinate at 28°C for 48 hours. Below 0.05 percent colchicine, germination was normal, greater than 90 percent, whereas in concentrations of colchicine from 0.1 to 1.0 percent there was a gradual decrease both in percent germination and branching of the germ tube. The percent germination decreased from 80 percent in 0.1 percent colchicine to 40 percent in 1.0 percent colchicine and no rudimentary mycelial mats formed at concentrations greater than 0.1 percent. The germ tubes were progressively shortened in 1.0 to 4.0 percent colchicine with no branching. Above 4 percent colchicine germination was only 10 percent and germ tubes were mere stubs.

Two methods of determining changes in the colony morphology were used: (1) exposing washed spores to the various concentrations of the reagent, allowing spores to germinate, and then plating them; (2) streaking normal spores on agar plates containing graded concentrations of colchicine. Three types of variation occurred with greater frequency than in the controls. The most frequent variants were normal, well-sporulating colonies with a sector of dead-white, asporogenous hyphae and some entirely asporogenous colonies, such as have been described by other investigators. The second variant was a slow growing asporogenous

colony which first appeared brown and butyrous with sparse aerial hypae. After 20 days the aerial hypae increased in number and length until at the end of 40 days the colony resembled the asporogenous variants. To determine whether this variant arose only after prolonged adsorption of colchicine on the germinating spore, the spores were washed in distilled water prior to plating them. This treatment did not decrease the number of such variants. The third type was a giant form, 19-25 mm. in diameter with otherwise normal appearance which arose only on agar containing 0.002 percent colchicine. None of the abnormal forms were stable and on subsequent transfer all reverted to the normal form.

Attempts to induce physiological variants of *Streptomyces griseus* which would produce abnormal yields of streptomycin were uniformly unsuccessful. Subcultures of normal and variant colonies developing from spores exposed to 0.001 to 5.0 percent colchicine were transferred to a corn steep soybean and Emerson media in shake flasks. The absence of variants with different capacities for producing streptomycin indicates that colchicine is a less favorable agent for this purpose than X-rays or ultra-violet light.

A SIMPLIFIED PLANKTON COUNTING METHOD

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The microscopic assemblage of life in lakes, ponds, streams and rivers, which is made up of both plant and animal forms, is known collectively as plankton. In 1882 Hensen was one of the first to attempt the study of these organisms quantitatively. His investigations were conducted on the Baltic and North seas with nets of various mesh sizes. It was soon found that even the finest meshed nets allowed many organisms to pass directly through.

Sedgwick (1888) and Rafter (1888), recognizing the inadequacy of the plankton net, both described methods of examining water microscopically after concentrating by filtration through sand supported on a bolting silk disk. This method has become known as the Sedgwick-Rafter method and is still widely used today.

In 1911 the extensive limnological program of Birge and Juday was started on the Wisconsin lakes and demanded a still more efficient and practical field plankton sampler. There evolved a portable centrifuge which is now known as the Foerst electric centrifuge. This instrument has been in use for more than thirty years and is recognized by the American Public Health Association, along with the Sedgwick-Rafter method, as the standard procedures for the examination of water and sewage (1946).

Several other devices or modifications, such as the Kofoid filter, the Juday plankton trap, the Clarke and Bumpus quantitative net sampler, have been developed and are in use. However, all require a considerable financial investment in equipment and supplies in addition to the microscope, which is the most fundamental. As a result, many may not have attempted quantitative work on the plankton because of the lack of what appears to be essential equipment. The writer believes that anyone possessing a microscope and an interest in the plankton is in a position to carry on a quantitative study of these organisms. This paper has been prepared with the beginner in mind and is not necessarily directed to the specialist in the field of biological productivity.

That it might be possible to secure reliable quantitative data quickly and without employing expensive equipment was first suggested by Baylis (1922) in a study of the microorganisms in the Baltimore water supply. In 1929, Baylis and Gerstein presented comparative counts made by the Sedgwick-Rafter and the Baylis direct count on the plankton in the Chicago water supply. The data indicated to the writer that the method deserved further consideration. Thus, while an employee of the City of Chicago working with both Baylis and Gerstein, routine plankton determinations were made with the Sedgwick-Rafter method, the Foerst centrifuge, and the direct count on an experimental basis.

TABLE 1

Order of Counts	Calculated No. of Organisms per ml from 10 areas	Percent Deviation from mean	Calculated No. of Organisms per ml from 50 areas	Percent Deviation from mean
1	1633	7	1962	8
2	2566	46	1555	15
3	1541	12	1700	7
4	1908	9	1695	7
5	2141	22	1805	1
6	1458	17	1927	6
7	1958	12	1860	2
8	991	44	1992	9
9	1933	10	1827	0.3
10	1416	19	1899	4
Mean	1755	20	1822	6

DIRECT COUNT METHOD

As the name implies, the direct count method does not require any concentration or special treatment of the water sample. A Sedgwick-Rafter counting cell or an improvised cell cut from an old piece of a tire inner tube and cemented to a glass slide serves the purpose very well. The usual inside dimensions of the Sedgwick-Rafter cell are 50 by 20 mm but for the direct count it is desirable to increase the area to at least 50 by 40 mm, which means doubling the volume ordinarily observed. Baylis recommends a 5 ml or even a 10 ml cell for making a rapid survey count in which the crustacean or larger organism population is established.

It should be noted that not even the Whipple ocular micrometer is required for the direct count, for instead of counting individual fields the whole length of the cell is traversed and the organisms encountered are enumerated. A minimum of 100 sq mm or two traverses of the 50 mm counting cell are recommended. Four strip counts across a 2 ml cell will increase the accuracy of the method. It is even more desirable to count 100 sq mm in two different 1 ml portions of the original common sample, and such practice should be encouraged. The time required to perform these strip counts is still less than it takes to prepare the samples and determine the count by either the sand filtration or the centrifuge methods.

The factor used for converting a concentrated sample count into actual numbers of organisms per ml is determined as follows:

$$\frac{\text{No. of fields in a 1 ml counting cell 1 mm deep}}{\text{No. of fields examined}} \times \frac{\text{Ml. of final concentrate}}{\text{Ml. of water concentrated}} = \text{The Factor}$$

For the direct count, all that is necessary is to know the area covered by the ocular, the number of fields in the counting cell, and the number of fields examined. Thus,

$$\frac{\text{No. of fields in the counting cell}}{\text{No. of fields examined}} = \text{The Factor}$$

Assuming that you have a one ml Sedgwick-Rafter counting cell (50 x 20 mm) and that you are using a 10 X ocular calibrated so that one field is equivalent to 1 square mil-

limeter, you would then have 1000 ocular fields in the total area of the counting cell. Therefore, if you counted 100 fields the factor would be

$$\frac{1000}{100} = 10 \text{ or the Factor}$$

If your check sheet shows a total of 67 organisms encountered in traversing 100 fields, the total number of organisms per ml of original water would be 670. Varying the size of the counting cell or the number of fields counted would only alter the mathematics involved. It is strongly recommended that the factor be maintained below 10, preferably at 5 or less. It could be accomplished in the example by simply counting 200 instead of 100 fields.

Precision of Counting Methods

The variation in successive counts in the same cell is considerable, even with the standard or approved methods, e.g. Sedgwick-Rafter and Foerst centrifuge. Littleford, et al. (1940) reported variations (table 1) on ten successive Sedgwick-Rafter concentrated counts when varying the areas or fields examined from 10 to 50.

It should be noted that the mean percent deviation in the ten individual counts from a concentrated sample, when 10 areas were counted, was approximately 20 percent with a maximum of 46 percent. By increasing the fields counted from 10 to 50, the mean percent deviation was decreased to approximately 6 percent.

At a rather low population density, the variation in a series of ten individual direct counts on the same one ml quantity of water determined by traversing 100 fields for each count was as follows:

Table 2

Order of Counts	Calculated No. of organisms per ml	Percent Deviation from the mean
1.....	550	12
2.....	410	36
3.....	470	26
4.....	960	51
5.....	790	24
6.....	580	9
7.....	670	5
8.....	530	17
9.....	820	29
10.....	580	9
Mean..	636	22

The mean percent deviation was found to be 22 with a maximum of 51 percent as a possible variation in the ten counts.

With a relative high population density (8000 per ml), ten strip counts across a 50 mm counting cell showed the following variation in actual number of organisms encountered:

Table 3

Order of Counts	No. of Organisms encountered in 50 mm	Percent Deviation from the mean
1.....	333	17
2.....	428	7
3.....	385	4
4.....	439	10
5.....	383	4
6.....	429	7
7.....	481	20
8.....	415	3
9.....	378	6
10.....	341	15
Mean....	401	9

The fact that with a standard method it is possible to get as much as a 46 percent deviation from the mean in its least accurate range would seem to indicate that the direct count with a 51 percent devi-

TABLE 4—COMPARISON OF PLANKTON COUNTS OF LAKE MICHIGAN WATER MADE BY THE DIRECT COUNT AND THE FOERST CENTRIFUGE METHODS AT CHICAGO, ILLINOIS, DURING SEPTEMBER, OCTOBER, AND NOVEMBER, 1946.

Month	No. of Samples	Average Number of Plankton per ml		Difference	Percent Deviation from the centrifuge
		Direct count	Foerst centrifuge		
September	50	841	810	31	4
October	29	974	916	58	6
November	29	1268	1179	89	8
Mean	36	1029	972	57	6

ation in its least accurate range might bear consideration and experimentation.

DIRECT COUNT VS. FOERST CENTRIFUGE

The first series of comparative counts was made on Lake Michigan water during September, October, and November of 1946. A total of 108 samples was examined for plankton organisms by both the direct count and the Foerst centrifuge methods. An approximately one liter lake water sample was collected and one ml was removed and immediately examined by the direct count. Organisms occurring in 100 fields were enumerated. As the control, one liter of the sample was concentrated to 10 ml by the Foerst centrifuge. One ml of the concentrate was then placed in the counting cell and the organisms in ten fields were enumerated. It is recognized that ten observations are usually considered the minimum when examining a concentrated sample and that the accuracy of the count can be increased by counting more fields. However, 100 fields are likewise considered the minimum allowable for the direct count; therefore, both methods were operating in their least accurate range.

The results show (table 4) that the direct count yielded a slightly higher mean for each month of the study. The percent deviation of the direct count from the centrifuge results increased with the population density from 4 to 8 percent. The direct counts show a mean deviation from the centrifuge results of only 6 percent during the entire three months of the study. It should be emphasized that this difference is the same as found for the Sedgwick-Rafter method when ten successive counts of 50 areas each were made on the same 1 ml of sample (Littleford, 1940).

DAILY FLUCTUATIONS IN PLANKTON POPULATIONS

Monthly averages as expressed in table 4 might leave the impression that the direct count always yielded higher counts than the Foerst centrifuge. Such is not the case. A casual observance of the daily counts found by each method (table 5) reveals what appears to be considerable variation from day to day and likewise between methods.

The problem of marked fluctuations in quantity of plankton from day to day is not new. It is evident in the data presented in most papers on biological productivity. It has been recognized that some of the difference is justifiably due to the precision of the method used. However, the marked similarities of the two curves representing population densities by two different methods seem to indicate that the organisms fluctuate much more than the methods of counting employed (fig. 1). If trends in population densities are the significant points to note, then it would appear that either the Foerst centrifuge or the direct count would serve the purpose equally well.

Sample Collecting

Verduin (in press) has recognized the inadequacy of the "station method" of sampling in Lake Erie because of the marked fluctuations in the daily counts. He has recommended the use of mobile collecting points which are traversed by boat over rather extensive areas of the lake. By so doing, the migration of the plankton populations can be followed and significance is then attached to the marked day-to-day fluctuations at any station.

If one were so fortunate as to have unlimited funds, the ideal method of sampling a lake or large body of water regularly would be by helicopter. Little time would be lost in moving from point to point and thus an even more accurate representation of plankton population waves or accumulations in specific areas could be established.

It seems quite evident that the method of collecting the sample for examination is probably more important than the selection of a method of counting, if we are to smooth out the daily fluctuations so often reported in plankton studies.

Table 5.—Comparison of Plankton Counts of Lake Michigan Water Made by the Direct Field Count and the Foerst Centrifuge Methods at Chicago, Illinois, During October, 1946.

Date	Direct	Centrifuged
10-1-46	1455	996
10-2-46	2305	1444
10-3-46	1865	984
10-4-46	600	874
10-5-46	580	796
10-6-46	625	532
10-7-46	395	390
10-8-46	1405	1380
10-9-46	1110	1384
10-10-46	1265	936
10-11-46	595	638
10-12-46	515	534
10-13-46	620	698
10-14-46	530	620
10-15-46	1060	1014
10-16-46	680	554
10-17-46	1130	1160
10-20-46	755	956
10-21-46	1185	1108
10-22-46	1190	1342
10-23-46	1450	1090
10-24-46	1265	844
10-25-46	1345	934
10-26-46	785	690
10-27-46	470	690
10-28-46	620	948
10-29-46	1040	1272
10-30-46	360	814
10-31-46	1060	928
Total	28260	26550
Mean	974	916

Direct Count vs. Sedgwick-Rafter Method

Beginning March 17, 1947, and continuing through April 15, 1947, plankton samples were collected daily from the raw Lake Michigan water, the chemically treated water, the settled or filtered water and from

TABLE 6.—DIRECT COUNT AND SEDGWICK-RAFTER METHOD COUNT ON WATER OF VARYING POPULATION DENSITIES IN THE SOUTH DISTRICT FILTRATION PLANT OF CHICAGO FROM MARCH 17, THROUGH APRIL 15, 1947.

Kind of Water	Sampling days	Average Plankton No. per ml		Difference
		Direct	Sedgwick-Rafter	
Raw water (untreated).....	30	614	414	200
Chemically treated.....	30	97	35	62
Settled (filtered).....	30	11	3	8
Outlet.....	30	15	6	9

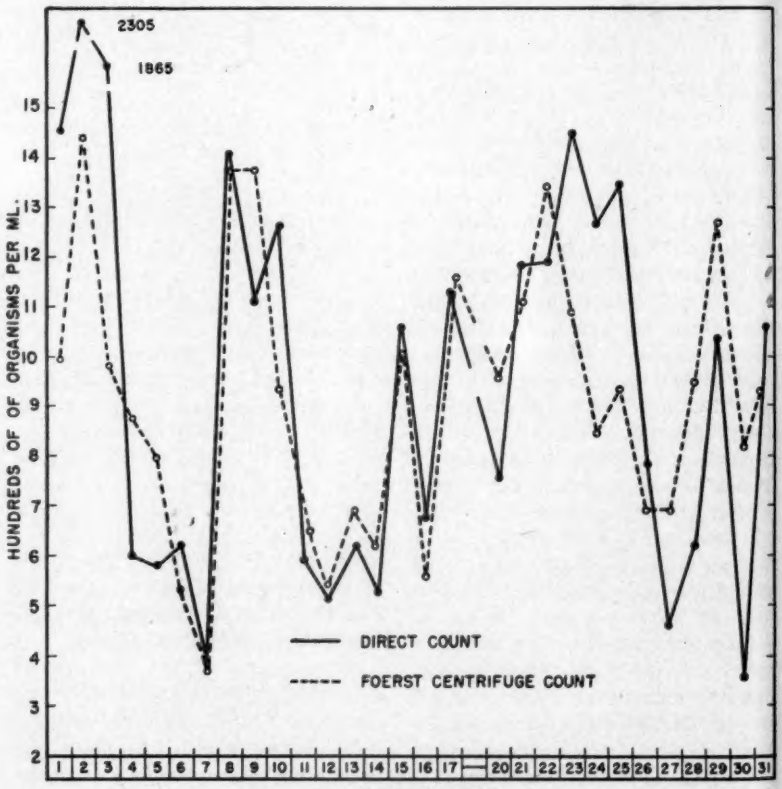

FIG. 1. Comparative plankton counts made by the Foerst centrifuge and the direct count methods on untreated or raw Lake Michigan water during October 1946.

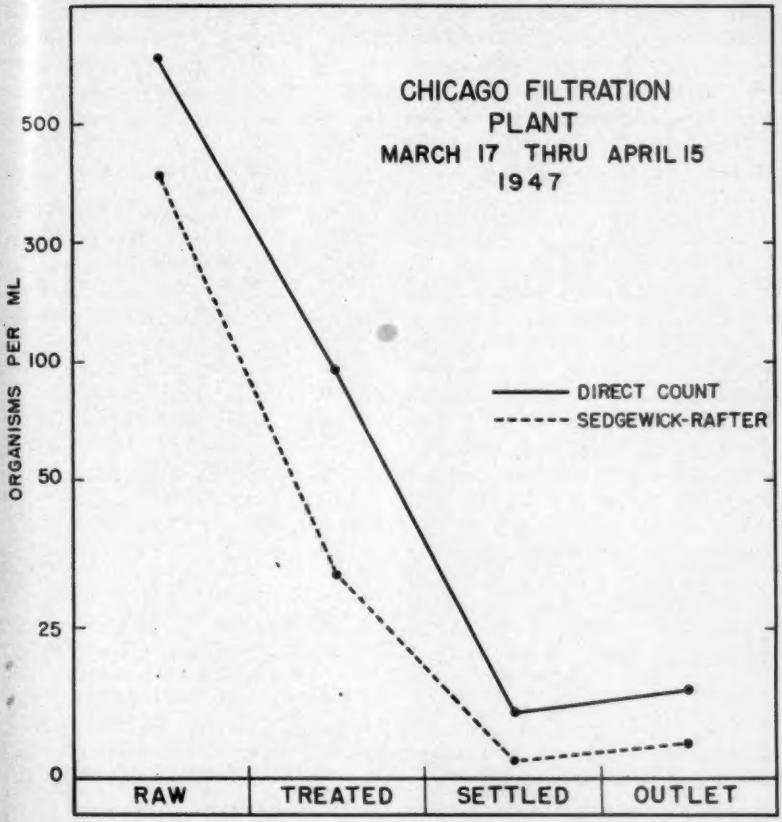

FIG. 2. Comparative plankton counts made by the Sedgwick-Rafter and the direct count methods on water of three different population densities.
Raw—Untreated Lake Michigan water.
Treated—Chemically treated and partially settled water.
Settled—Settled and filtered water.
Outlet—Mixture of treated and settled water.

the outlet water of the Chicago filtration plant. Both the direct count and the Sedgwick-Rafter methods were used on the same common sample. By using the raw, treated, and settled water, the two methods were compared at three quite different population densities. The outlet water during the study was a mixture of treated and settled water.

The direct count yielded a considerably higher average plankton number in all of the population densities (table 6). Yet both curves (fig. 2) followed the same general trend. Which method is nearer to the actual number of organisms present is not of greatest concern. It is important that both methods are consistent. It would appear that for a routine record of the efficiency of plankton removal in a water

plant, the direct count is as reliable as the Sedgwick-Rafter method and is much less time-consuming. For taxonomic or qualitative work on species, a tow net sample or some other means of concentration would always be recommended over the direct count method.

Summary

A simplified method of counting plankton organisms by direct observation without concentration has been described. In routine microscopic examinations over extended periods of time, the results by the direct count have been compared with the Sedgwick-Rafter and the Foerst centrifuge methods.

The data presented seem to indicate that for simplicity, economy, consistency, and convenience the direct count without concentration of the sample is highly satisfactory and often desired over other more involved and expensive methods.

Acknowledgments

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UTILIZATION OF SOME ORGANIC ACIDS BY *STREPTOMYCES GRISEUS* FOR STREPTOMYCIN PRODUCTION AND GROWTH

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Studies on the utilization of some organic acids by *Streptomyces griseus* (Krainsky) Waksman and Henrici, 1943 (33, 35) were undertaken to ascertain further information on the nutritional capacity of this microorganism in connection with streptomycin production. Such studies were favored by the availability of a synthetic medium for the production of streptomycin by this organism (28, 31). They also logically accompany the previous studies on the utilization of some sugars by this organism (17) since both glucose and lactate are important carbon constituents of the chemically defined medium (28, 31). At the time of initiating these studies in 1946, no reference was found relative to this organism utilizing organic acids[2] except malic acid (33).

Methods and Materials

The chemically defined basal medium used throughout these studies was a modification of the original synthetic medium (28) that permitted the addition of organic acids in varied amounts as substitutes for the lactic acid. It consisted of the following constituents of C. P. and Reagent grades:

Substance	Amount	Concentration (Final Molarity)
Glucose (Cerelose)	10. g.	0.0550
KH_2PO_4	2.38 g.	0.0176
$K_2HPO_4.3H_2O$	5.65 g.	0.0247
NH_4NO_3	4.00 g.	0.0500
$Mg\ SO_4.7H_2O$	1.00 g.	0.0040
$Zn\ SO_4.7H_2O$	0.0115 g.	0.00004
$Fe\ SO_4.7H_2O$	0.0111 g.	0.00004
$Cu\ SO_4$	0.0064 g.	0.00004
$Mn\ Cl.4H_2O$	0.0070 g.	0.00004
Distilled water	500 ml.	(1000 ml.)
(H-ion concentration adjusted to pH 7.0 ± 0.1 when necessary)		

In preparing the complete medium for each of the varied amounts of organic acids (racemic mixtures of the optically active acids), the necessary amounts of the organic acid in aqueous solution neutralized with NaOH to pH 7.0 was added to 75 ml. of the double strength basal medium. Distilled water was then added to make 150 ml. volume. Fifty ml. of this complete medium was then placed in 125 ml. Erlenmeyer flasks in triplicate and sterilized by autoclaving at 121°C. for 15 minutes. The organic acids used were those readily available.

The culture of *Streptomyces griseus*[3] used throughout these studies was a subculture of Waksman's strain No. 9 from No. 18-16 origi-

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[2] Referred to as acids rather than sodium salts of organic acids for brevity.

[3] Letter from S. A. Waksman to H. W. Anderson, September 1, 1944.

nally obtained from heavily manured field soil (26).

Other items of procedure involved the following methods and conditions:

(a) The inoculum, consisting of 3 or 4 drops of suspended fragments of mycelium, was applied to the surface of the medium (17).

(b) Growth conditions consisted of surface stationary culture (air surface of 0.5 cm^2/ml. of medium 2 cm. deep) and 26°C. for 10 days.

(c) Growth in 10 days was estimated qualitatively on an arbitrary scale of 0 to 10 and where adequate it was determined quantitatively as vacuum dried (80°C.) mycelial mat weight.

(d) The pH values were determined with a glass electrode Beckman pH meter.

(e) Streptomycin was determined in duplicate assays by the paper disc-plate method against *Bacillus subtilis* cultured at 30°C. (19). The fermented medium was diluted 1-4 in 0.1 molar phosphate buffer at pH 7.8 for the assays. Streptomycin values are reported as "S Units" of streptomycin per ml. (34). One "S Unit" of streptomycin is approximately one microgram of streptomycin free base (36).

(f) The effect of the nutritive acids on the assay of streptomycin was measured by mixing the acids individually at 0.1 molal final concentration with solutions of streptomycin six hours prior to assay in the usual procedure.

(g) The effect of these acids upon growth of the test organism in the assay plates was determined by applying them individually at 0.1 molal to the assay discs as in (f) above but without streptomycin.

Experiments and Results

For a preliminary survey on utilization, some organic acids were each evaluated at 0.05 molal in the basal synthetic medium. The results in table 1 indicate that some acids are not utilized at 0.05 molal. In fact, these acids either retard or inhibit the growth of *Streptomyces griseus*. These are butyric, a-hydroxy-e-benzoylamino caproic, monochloroacetic, crotonic, glycollic, formic, mandelic, oxalic, and tannic acids. Some other acids either do not affect the organism or affect it too slightly to yield noticeable comparative changes in pH, growth, or streptomycin production from the control of basal medium. These are tartaric (Na and Na and K salts) and tartronic acids. Other acids appear to be utilized. These are acetic, adipic, citric, glutaric, lactic (control), malic, malonic, and succinic acids.

Those acids that did not noticeably inhibit or retard growth at 0.05 molal were evaluated over a range of concentration. It was thought that results from this procedure should reveal whether utilization of organic acids might be related to concentration or to a suitable balance of these substances with other constituents in the medium. The results are given in charts (figs. 1 to 10) in order to show the relationship of three responses (pH, growth, and streptomycin production) to concentration of nutritive acid. These responses do not necessarily parallel each other or show any constant relationship with respect to either concentration or type of acid. The composite results in the charts indicate that these acids are utilized in some manner and to some extent by the organism in its metabolism under these conditions.

TABLE 1.—UTILIZATION OF ORGANIC ACIDS AT 0.05 MOLAL BY STREPTOMYCES GRISEUS IN STATIONARY CULTURE AT 26°C.

Acid	pH Initial	pH Final	Growth (10 days)	Mat weight (mg)	Streptomycin (units/ml)
Acetic	6.88	7.74	8	274	52
Adipic	6.83	6.92	10	323	48
Butyric	6.72	6.55	0	...[a]	0
a-hydroxy-e-benzoylamino caproic	6.83	6.0	3	...	20
Monochloroacetic	6.35	6.3	0	...	0
Citric	6.79	8.25	4	...	52
Crotonic	6.8	6.62	0	...	0
Formic	6.78	6.61	3	...	0
Glutaric	6.85	6.60	10	285	53
Glycollic	6.78	5.8	7	...	24
Lactic	6.75	7.96	10	442	61
Malic	6.85	8.5	10	357	63
Malonic	7.0	6.82	10	325	37
Mandelic	6.7	5.95	1	...	0
Oxalic K salt	6.64	5.38	2	...	12
Oxalic Na salt	6.83	5.84	2	...	18
Tannic	6.8	6.5	0	...	0
Tartaric Na salt	6.94	6.17	9	260	39
Tartaric Na K salt	6.7	5.69	8	...	31
Tartronic	6.82	6.2	8	250	36
Succinic	6.9	8.40	10	425	83
Control	6.71	6.25	9	205	46

a. Value not determined.

Alkalinity of the medium in all cases except for two organic acids (tartaric and tartronic acids causing only minor changes) increased with the increase of nutritive acid concentration up to an optimal concentration at about 0.1 molal. Growth in all cases was related to the nutritive acid concentration. The optimal concentration was found to be about 0.05 molal for acetic, citric, and glutaric; about 0.1 molal for adipic, lactic, malic, succinic, tartaric, and tartronic; and about 0.3 molal for malonic acid. Streptomycin yields evidenced by the assays indicated that the concentration of nutritive acid influenced production. Only lactic acid supported sizable production of streptomycin. Its optimal concentration was 0.1 molal.

The effect of these utilizable acids upon the growth of the test organism in the assay plate is nil. Their effect on the assay of streptomycin is practically nil. These results, as means of six determinations, are summarized by expressing them as a ratio of the size of zones of inhibition from streptomycin with acids to that from streptomycin alone—"Acid/Control Index." The computed "Acid/Control Indices" for the acids are acetic 1.02, adipic 1.04, citric 1.02, glutaric 0.90, lactic 1.01, malic 1.08, malonic 1.06, succinic 1.04, tartaric 1.00, and tartronic 1.05. These indices are based upon a mean 17.75 mm. zone of inhibition for the streptomycin control.

DISCUSSION

The discussion offers some summary interpretations from the overall results on three measured responses of the organism; it presents some

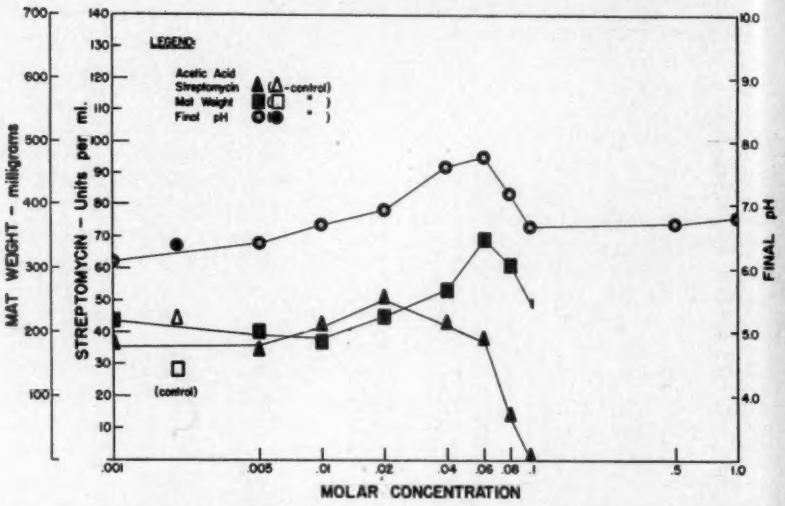

FIG. 1.—Effect of acetic acid at varied concentrations on *Streptomyces griseus* in stationary culture at 26° C.

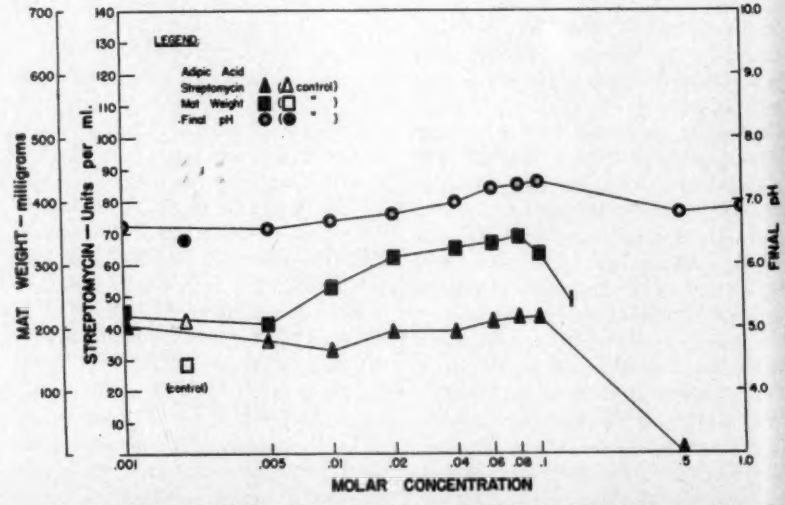

FIG. 2.—Effect of adipic acid at varied concentrations on *Streptomyces griseus* in stationary culture at 26° C.

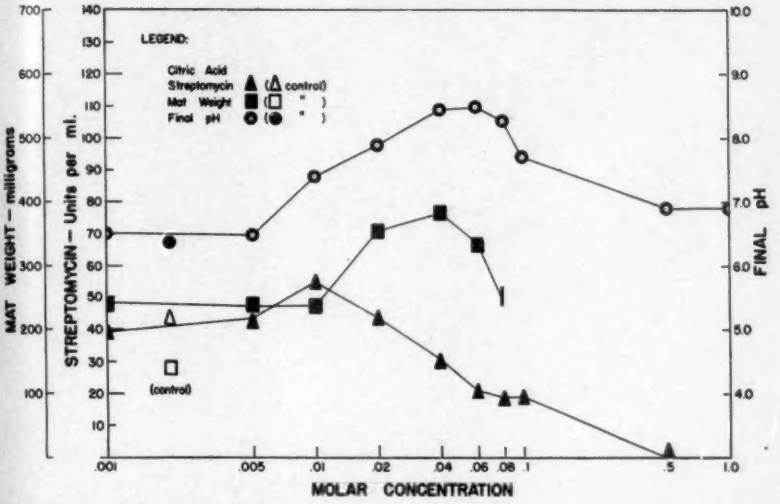

FIG. 3.—Effect of citric acid at varied concentrations on *Streptomyces griseus* in stationary culture at 26° C.

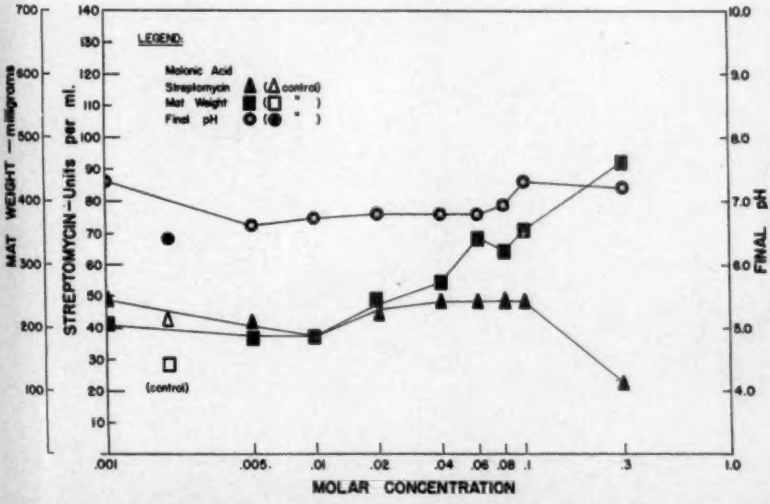

FIG. 4.—Effect of malonic acid at varied concentrations on *Streptomyces griseus* in stationary culture at 26° C.

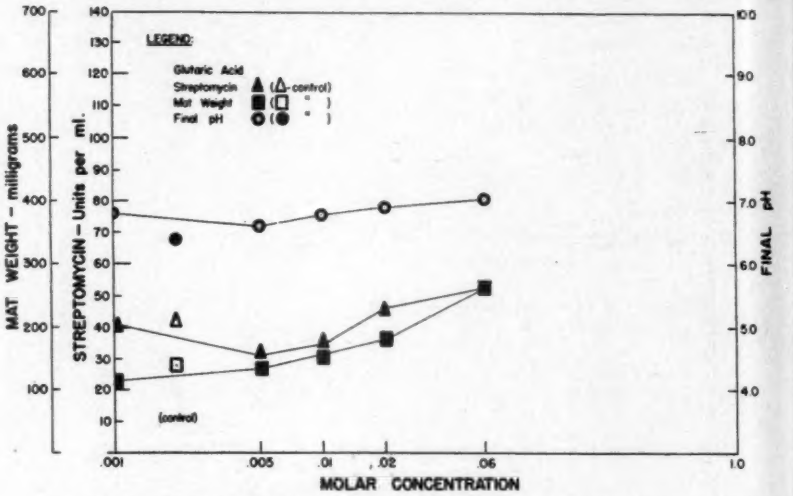

FIG. 5.—Effect of glutaric acid at varied concentrations on *Streptomyces griseus* in stationary culture at 26° C.

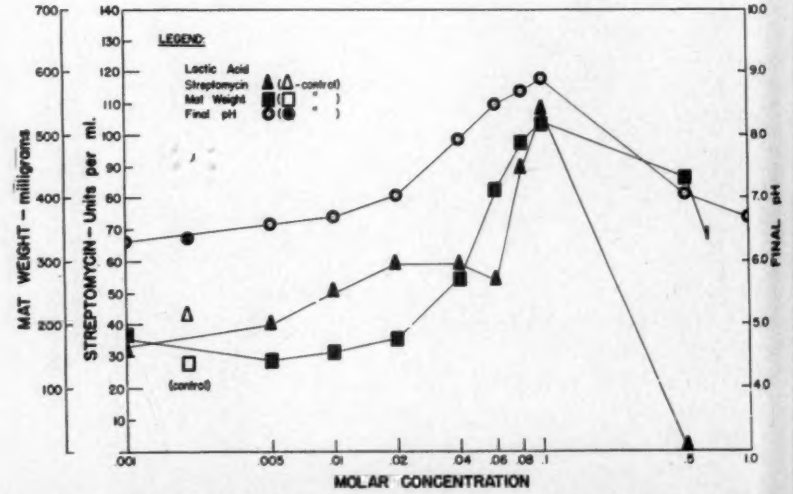

FIG. 6.—Effect of lactic acid at varied concentrations on *Streptomyces griseus* in stationary culture at 26° C.

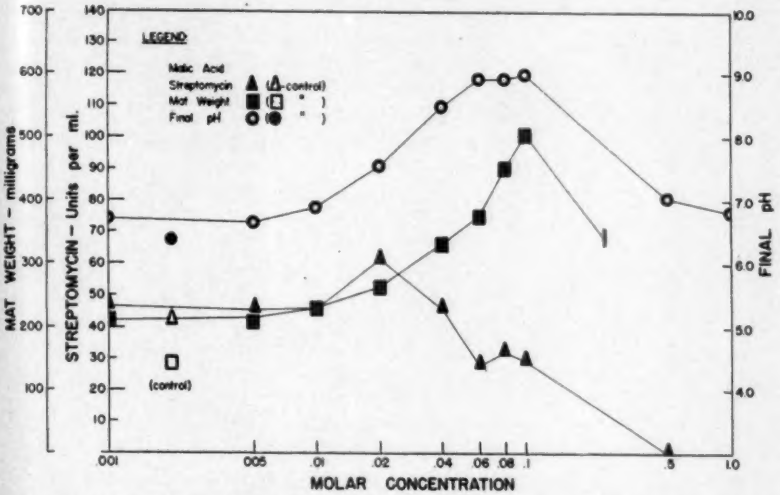

FIG. 7.—Effect of malic acid at varied concentrations on *Streptomyces griseus* in stationary culture at 26° C.

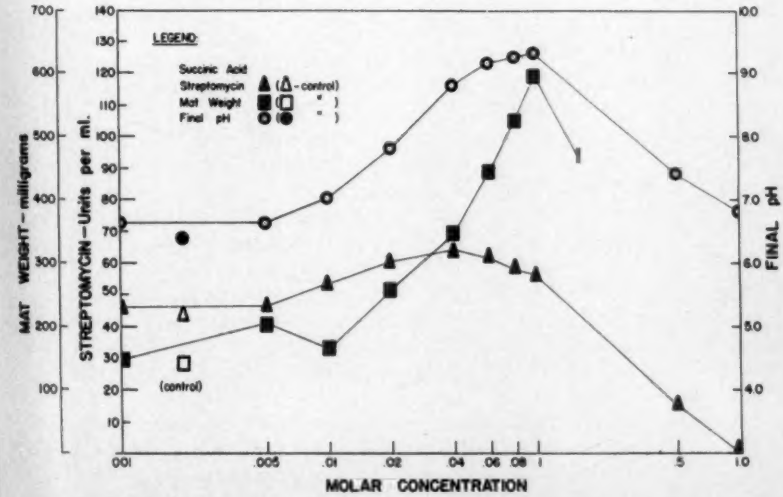

FIG. 8.—Effect of succinic acid at varied concentrations on *Streptomyces griseus* in stationary culture at 26° C.

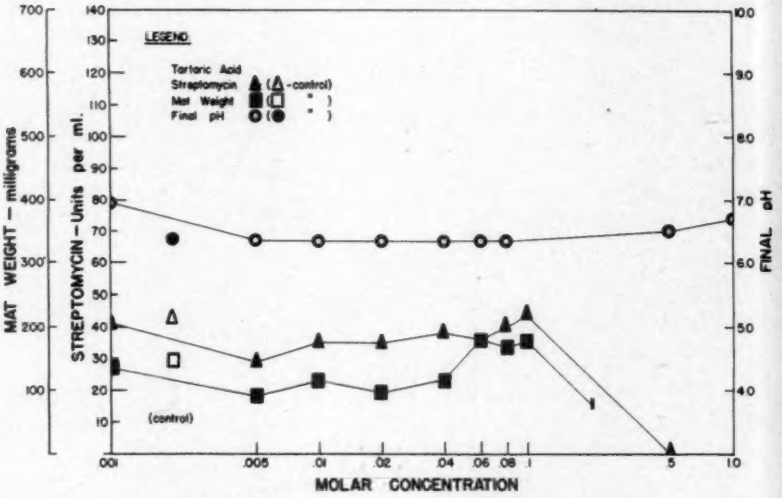

FIG. 9.—Effect of tartaric acid at varied concentrations on *Streptomyces griseus* in stationary culture at 26° C.

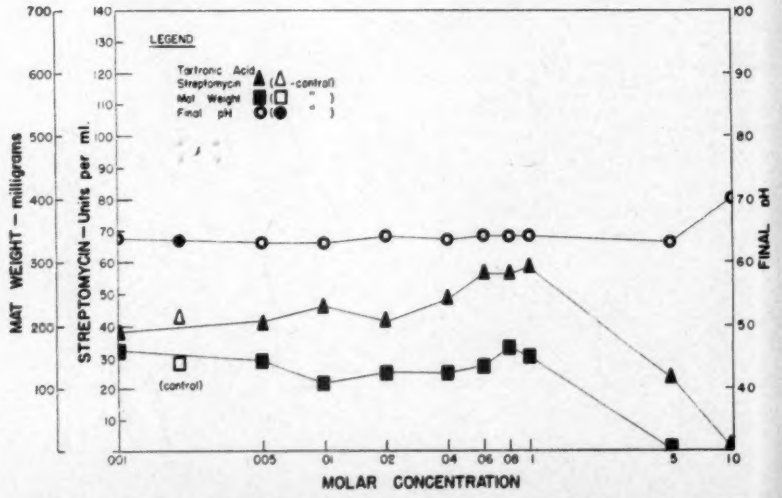

FIG. 10.—Effect of tartronic acid at varied concentrations on *Streptomyces griseus* in stationary culture at 26° C.

considerations with respect to safeguards against artifacts in the data; it advances some speculations relative to the role of trace elements for organic acid utilization, to organic acids influencing metabolic mechanisms, and to lactic acid in streptomycin synthesis. The speculations are included for the sole purpose of attempting to keep the small sector represented by this study oriented at least toward the composite picture of microbial metabolism.

The results from this study extend the information relative to the assimulative and dissimulative capacity of *Streptomyces griseus* for sources of carbon beyond some sugars (17). Although the results are based upon indirect criteria for utilization, they contribute to a preliminary qualitative survey of carbon sources. In addition, the results establish certain basic information by designating some growth inhibitive acids and by indicating differences among utilizable acids.

The three measured responses (pH, growth, and streptomycin production) associated with the metabolism of the organism appear to show a maximum at some range of concentration of each organic acid except for (a) pH in the medium containing glutaric, tartaric, and tartronic acids and (b) streptomycin production in media containing glutaric acid. In the case of glutaric acid, the highest concentration used may have been inadequate to indicate an optimal concentration. An optimal concentration is apparent for each of the other organic acids in the medium as has been found for sugars (17) and for various constituents of the synthetic medium (28, 31). Since these respective optimal concentrations for the three responses occur, for the most part, at different amounts of the acids, they suggest that different metabolic mechanisms are involved in these responses. Similar unparalleled responses are evident in connection with the optimal concentrations of sugars (17) and constituents of the original synthetic medium (28, 31). They have been noted under some other conditions (9, 12). However, the three responses were somewhat parallel with lactic acid, the optimal concentration of which was 0.1 molal for each response.

The H-ion concentration of the medium being related to the balance among ionizable acidic and basic substances at the time of the pH measurements would result from the accumulation of either the residual materials following the assimulation of original constituents of the medium or the end products of metabolism. Metabolites that are consumed as they are produced by the organism would not appreciably affect pH. Thus, the measured increase in alkalinity apparently originates from the accumulation of basic sodium ions or basic end products in the medium. Either of these accumulations would indicate utilization of the acids since the alkalinity is relative to the original concentration of nutritive acid in the medium. It is doubtful whether tartaric and tartronic acids are utilizable (figs. 9, 10). This agrees with another report claiming non-utilization of tartaric acid (23). It is apparent that all the other acids tested at varied concentrations are utilizable (figs. 1 to 8). If organic acids are produced during metabolism, it would appear that these are in turn utilized. It has been reported that organic acids are not produced by Strain No. 4 of *S. griseus* (6) and that the end product of metabolism

of this organism in submerged culture is CO_2 rather than organic acids (8). By escape of this gaseous end product there would be a tendency for any basic non-volatile residues and end products to overbalance the acidic residues and metabolites in the medium. Such could account for the rise in alkalinity usually encountered with this organism. However, if the concentration of glucose is particularly high in a synthetic medium, the reaction does not become more alkaline but becomes acid during fermentation for a period of time (31).

Growth responses of the organism, since they are affected by concentration of the acids, appear to be satisfactory evidence of utilization of these substances. By combining these responses with the somewhat parallel responses in alkalinity changes, these criteria for utilization become more reliable. Growth is better on lactic, malic, and succinic acids than other acids.

Streptomycin production according to the activity detected by the assays is not appreciably increased by any of the acids except lactic acid, a constituent of the original synthetic medium (28,31). Although production from the other acids was not great, there appears to be some relationship of streptomycin yield to concentration of the acids (figs. 1 to 10). Because these optima for streptomycin production with the exception of lactic acid are not the same as those for growth, it appears that the optimal concentration of such nutrients for growth may be "out of balance" for streptomycin production. Along this reasoning, lactic acid at 0.1 molal is "in balance" with other nutrients for growth and streptomycin production simultaneously. As lactic, malic, and succinic acids contributed marked responses in pH and growth, with streptomycin being produced in any appreciable amount only from lactic acid (figs. 6, 7, 8), it appears that lactic acid may specifically contribute to the production of streptomycin by this organism. Mechanisms of metabolism or nutrition favoring the production of lactic acid might conceivably stimulate growth of the organism with appreciable production of streptomycin, whereas good growth without lactic acid being supplied or produced in the medium might result in low yields of streptomycin.

Neither the assay of streptomycin nor the growth of the assay organism on the assay plates was appreciably affected by any of the organic acids at 0.1 molal. However, it has been reported that salts of some of these acids antagonize the action of streptomycin (3, 4, 7, 10, 13, 14, 16) and also effect the growth of test organisms for assay (7, 18, 36). These discrepancies may be explainable in differences among the test organisms used or conditions of the assays. In the paper-disc assay plate method only substances that would diffuse faster than the streptomycin would be able to affect the test organism. In addition, the method is insensitive to substances such as alcohol that might affect the test organisms suspended in a liquid culture (30).

The osmotic concentrations of the various media do not solely influence the optimal concentrations of acids since the optima did not occur at any one concentration. However, the physical effect of the higher concentrations (0.615 molal for 0.5 molal acids) would be expected to influence the functions of the organism (physiological salt solution being 0.155 molal NaCl although based

upon human red blood cells). Since abrupt changes in the responses occurred generally at 0.1 molal (0.215 total molal concentration), the isotonic concentration of the organism (although undetermined) would be expected to be slightly above this total molal concentration. It has been reported that a reduction of NaCl concentration in the medium accounts for a relatively greater amount of streptomycin recoverable from the mycelium than from the medium (9). According to this, the higher concentrations of sodium salts of the organic acids where reduced streptomycin production occurred should favor the release of streptomycin into the medium and thus permit adequate assay of the streptomycin actually formed. Sodium chloride has been reported to stimulate the production of streptomycin in a soybean medium (25).

The relation of trace elements in the medium to the utilization of organic acids is not apparent from the observations and data of this study. However, in other studies trace elements in a medium containing both glucose and lactic acid influenced growth and streptomycin production (28, 31). Also the minerals remaining in the ash of some animal and plant products stimulated growth and streptomycin production (29). In addition to influencing the growth of microorganisms, trace elements are known to alter the metabolism of microorganisms so as to favor the accumulation of commercially desired end products of metabolism such as citric acid (22). Even without the presence of organisms, they can catalyze the oxidation of sugars to organic acids in acid or alkaline solutions when molecular oxygen is supplied (11). They also increase the ionization and reactivity of sugars as acids (11). These phenomena and the fact that some organic acids are utilized by *S. griseus* and other actinomycetes (2, 33) suggest that this organism may utilize organic acids through some mechanism involving metallic trace elements.

Lactic acid appears to play a role in streptomycin production by *S. griseus*. The acid is known to function in CO_2 fixation by *Clostridium butylicum* (5). Carbon dioxide appears to be necessary for some actinomycetes in synthetic media (1) and either CO_2 or the carbonate radical appears to influence streptomycin production by *S. griseus* (31). A lactic acid forming enzyme is inactivated at 37° C. (20), the temperature at which *S. griseus* does not produce streptomycin even though good growth continues (31). Since lactic acid is rapidly consumed by *S. griseus* (31) and is unique among the acids studied for streptomycin production, the synthesis of streptomycin by this organism might conceivably be dependent upon lactic acid which may be supplied to the medium or produced by the organism itself for assimulation or dissimulation (31).

Any effect of streptomycin upon the metabolism of *S. griseus* which produces it is not directly revealed by the data. However, the data do suggest some presumed evidence and inferences for streptomycin effects. Since streptomycin appears to affect the oxidation of acetate by *Escherichia coli* (21) and animal tissue homogenates (32), streptomycin might conceivably influence the oxidative system of *S. griseus* with respect to organic acids if these acids should be broken down to a two-carbon acid such as acetic (15). Such an influence might retard further

synthesis of streptomycin even though growth is excellent when the medium contains nutrients of particular substances such as malic and succinic acids. If lactic acid should afford other or additional mechanisms, the synthesis of streptomycin might not be retarded when lactic acid is available. This would explain the occurrence of higher production of streptomycin from lactic acid than from other acids when growth is approximately equal on the acids concerned.

Another possible explanation is that the acids other than lactic may channel the mechanisms of the organism away from streptomycin synthesis or may direct the mechanisms into streptomycin utilization. Lactic acid, on the other hand, may channel the mechanisms away from streptomycin utilization and toward streptomycin synthesis. Streptomycin is utilized by some microorganisms (24) but no report was found where an organism could produce streptomycin or an antibiotic under some conditions and under certain other conditions could utilize it.

It should be kept in mind that a supposedly pure culture of this organism may mutate into strains (27) or carry strains that possess quite distinct functional characteristics. Such inductions or selections might be brought about by the organic acids in the medium, as growth in these experiments involves successive generations from a small quantity of the inoculum. Organic acids in certain respects might be considered as metabolites which could be more effective than the less oxidized aldehydes (sugars as conventional carbon sources) in influencing metabolic mechanisms. Organic acids are end products of metabolism of many microorganisms (22, 37) and even species of *Streptomyces* (6). The absence of organic acids detectable as end products (6) does not necessarily mean that *S. griseus* is incapable of producing organic acids. It has been reported that *S. griseus* forms very little acid from glucose and no succinic acid during active growth although traces of succionate appear in later stages of growth (6). Organic acids might be formed but if they are rapidly utilized they would not become concentrated sufficiently for detection by usual methods of analysis. The evidence for utilization of organic acids reported herein and mentioned above (6) suggests that organic acids may be significant nutrients or metabolites that influence streptomycin production.

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CHEMISTRY

METHOXYL DETERMINATIONS ON ALKYL ESTERS OF 2-METHOXYBENZOIC ACID*

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In the course of another investigation it became desirable to ascertain to what extent certain alkyl ester groups would interfere with methoxyl determinations made on derivatives of methoxy-aromatic acids.

The Zeisel method in its various modifications has long been used, on both macro and micro scale, for the determination of methoxyl and ethoxyl groups; with certain changes in apparatus and technic, it has been recommended for propoxyl and butoxyl determinations[1]. It might be inferred, therefore, that a methoxyl determination by the usual procedure could be carried out without interference by pentoxyl groups. That this is not the case is shown here.

The ready availability of salicylic acid made it convenient to use as a starting material for the preparation of suitable test compounds. This paper reports the preparation and properties of the n-propyl, n-butyl, and n-pentyl esters of 2-methoxy benzoic acid, and results of methoxyl determinations made upon them by the micro Zeisel method.

Of the simple alkyl esters of 2-methoxybenzoic acid, only the methyl[2] and ethyl[3] esters have been described in the literature.

EXPERIMENTAL

2-Methoxybenzoic acid. This compound was prepared by methylating salicylic acid with dimethyl sulfate and purifying the product according to the method of Graebe[4]. One mole (138 g.) of salicylic acid yielded 95.3 g. of 2-methoxybenzoic acid (62.7% of theoretical); recovery of salicylic acid was 32.8 g., making the yield of desired product 81.8% based on salicylic acid actually used. The melting point was 101.5-103.5°C. after recrystallization from water.

Esters of 2-methoxybenzoic acid. As typical of the method used, the preparation of n-butyl 2-methoxybenzoate is described here. The procedure was essentially that used by Cavill and Gibson[5] for making n-butyl 4-methoxybenzoate. A solution of 30.4 g. (0.2 mole) of 2-methoxybenzoic acid in 100 ml. of n-butanol and 100 ml. of toluene was treated with 10 drops of concentrattrated sulfuric acid, and refluxed until no more water accumulated in the graduated trap which was interposed between the flask and the condenser. In about three hours 4 ml. of water were caught (theoretical 0.2 mole = 3.6 ml.). The reaction mixture was cooled, washed with water, sodium carbonate solution, water, dried over anhydrous sodium

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[1] See, for example, Sidney Siggia, "Quantitative Organic Analysis via Functional Groups," p. 30, John Wiley and Sons, Inc., 1949.

[2] See Beilstein, "Handbuch der Organischen Chemie," 4th Edition, Vol. X, p. 71; 1st Supplement X, p. 32.

[3] Ibid. Vol. X, p. 74; 1st Supplement X, p. 34.

[4] Ann. *340*, 210; *139*, 137; cf. Beilstein X, p. 64.

[5] G. W. K. Cavill and N. A. Gibson, J. Soc. Chem. Ind. *66*, 274, 1947.

TABLE I.—METHOXYL DATA FOR 1, 2-C_6H_4 (COOR) (OCH_3).

R	Theoret. OCH_3	—OR found (as —OCH_3)	Flushing time (Minutes)	Number of alkoxyl groups
n-C_3H_7	15.98	30.16	45*	1.89
n-C_4H_9	14.90	28.28	45*	1.90
n-C_5H_{11}	13.96	17.64	20	1.26
n-C_5H_{11}	"	26.72	80	1.91
n-C_5H_{11}	"	27.16	90	1.95

* Approximate.

sulfate, the butanol and toluene distilled off, and the product distilled at diminished pressure. The yield was 38.3 g. or 92% of the theoretical. This was redistilled through a short column prior to analysis. Boiling point, 112°C. at 1.2 mm.; f.p., —23° to —25°; n_D^{20}, 1.51125; d_4^{20}, 1.062. Analysis: Calcd. for $C_{12}H_{16}O_3$: C, 69.21; H, 7.74. Found: C, 69.22; H, 7.68.

The n-pentyl ester, prepared in a similar manner from 15. 2 g. (0.1 mole) of 2-methoxybenzoic acid, 25 g. of pentanol-1, 75 ml. of toluene and 3 drops of sulfuric acid, was isolated in 69% yield. B.p., 112-13° at 0.8 mm.; n_D^{20}, 1.50668; d_4^{20}, 1.045. Anal.: Calcd. for $C_{13}H_{18}O_3$: C, 70.24; H, 8.16. Found: C, 70.03; H, 8.19.

In the preparation of the propyl ester, 150 ml. of benzene were used in place of toluene, with 30.4 g. of the acid, 60 ml. of propanol and 2 ml. of sulfuric acid. The crude ester, 37.1 g. or 95.6% of theoretical, required several redistillations before it was sufficiently pure for analysis. B.p., 114.8-115.5° at 1.5 mm.; n_D^{20}, 1.51566; d_4^{20}, 1.085. Anal.: Calcd. for $C_{11}H_{14}O_3$: C, 68.02; H, 7.26. Found: C, 67.88, 68.10; H, 7.44, 7.44.

A small sample of each of the esters was saponified and the 3, 5-dinitrobenzoate was prepared from the alcohol formed. The derivatives thus produced were those of the normal alcohol proving that no rearrangement of the alkyl groups had occurred during esterification.

Methoxyl determinations were run essentially as described by Pregl[6], with variations in the length of the flushing period. Table I gives the results of these determinations, and shows the effect of varying the fushing period in the case of the pentyl ester.

It is thus shown that even with the normal 20-minute flushing period, the presence of n-pentyl ester groups results in a high value for methoxyl, and that with longer flushing periods, both ether and ester alkoxyl groups in these compounds can be determined with a fair degree of completeness.

SUMMARY

Three new compounds have been described and their physical constants reported. These are the n-propyl, n-butyl, and n-pentyl esters of 2-methoxybenzoic acid.

In all cases the alkoxyl groups present as esters have been split off with hydriodic acid, and the resulting alkyl iodides have distilled over along with methyl iodide from the ether group in the micro Zeisel methoxyl procedure.

[6] Pregl-Grant, "Quantitative Organic Analysis," p. 146, The Blakiston Co., 1946.

THE KOLBE ELECTROCHEMICAL SYNTHESIS: AN ACADEMIC TOPIC

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The electrolysis of organic-acid salts initiated by Kolbe in 1849 remains one of the most direct approaches to the study of free radicals. The concentrated potassium acetate which he first used is excellent for demonstrating this experiment. This solution is made by saturating water with solid potassium acetate and adding about five percent of the volume of glacial acetic acid. It is both anolyte and catholyte. The cathode is copper wire gauze. The anode is platinum foil, secured through a rubber stopper in a porous cup. A glass tube through this stopper permits the gaseous products of the electrolysis to escape from the reaction chamber. They pass through a U tube containing glass beads and 6 N. aqueous NaOH solution, then through another U tube containing glass beads and conc. H_2SO_4; thence they are led to a pneumatic trough for collection. Neither dimensions of the apparatus nor concentrations of the solutions are critical. Also the electrolyzing voltage may vary within rather wide limits. It may be as little as 8 volts or even less if the experiment may be started some hours ahead of class time; but if 15 to 20 volts[1] are available, the experiment may be started with the start of the lecture, and will in a few minutes yield sufficient ethane for a burning test. It is one of the few organic chemistry experiments well-adapted for lecture demonstration.

To interpret it from the free-radical viewpoint is a fine exercise in visualization of molecular behavior. The starting material is acetic acid; the products are cathodic hydrogen, and anodic carbon dioxide and ethane, mainly; though some ethylene, methanol, and methyl acetate are also formed at the anode. The following sequence of events is presumed to explain these results:

(a) Before electrolysis—ionization of solvent and salt, the former only slight.

(b) At cathode—arrival of cations K^+ and H_3O^+, with selective discharge of latter (see activity series) with production of H_2.

(c) At anode—arrival of anions $CH_3 \cdot COO^-$ and OH^-, with selective discharge mainly, but not exclusively, of the former, producing the free radicals $CH_3 \cdot COO$ and OH[2]. Each of these contains an odd number of electrons.

(d) Decomposition of some $CH_3 \cdot COO$ into CH_3 and CO_2, (and some OH into O_2 and H_2O). The new free radical thus formed contains also an odd number of electrons.

(e) The formation of all possible stable combinations of the three free radicals present. The radicals are (1) $CH_3 \cdot COO$, (2) CH_3, (3) OH. The stable products predicted and found are: $CH_3 \cdot CH_3$, $CH_3 \cdot COO \cdot CH_3$, and CH_3OH, besides the CO_2. In the demonstration, the NaOH in

[1] External cooling is advisable with higher voltages.

[2] The $CH_3.COO.OOC.CH_3$ and HO.OH postulated as intermediates in current theories of this synthesis would be in equilibrium, theoretically, with the two prime free radicals.

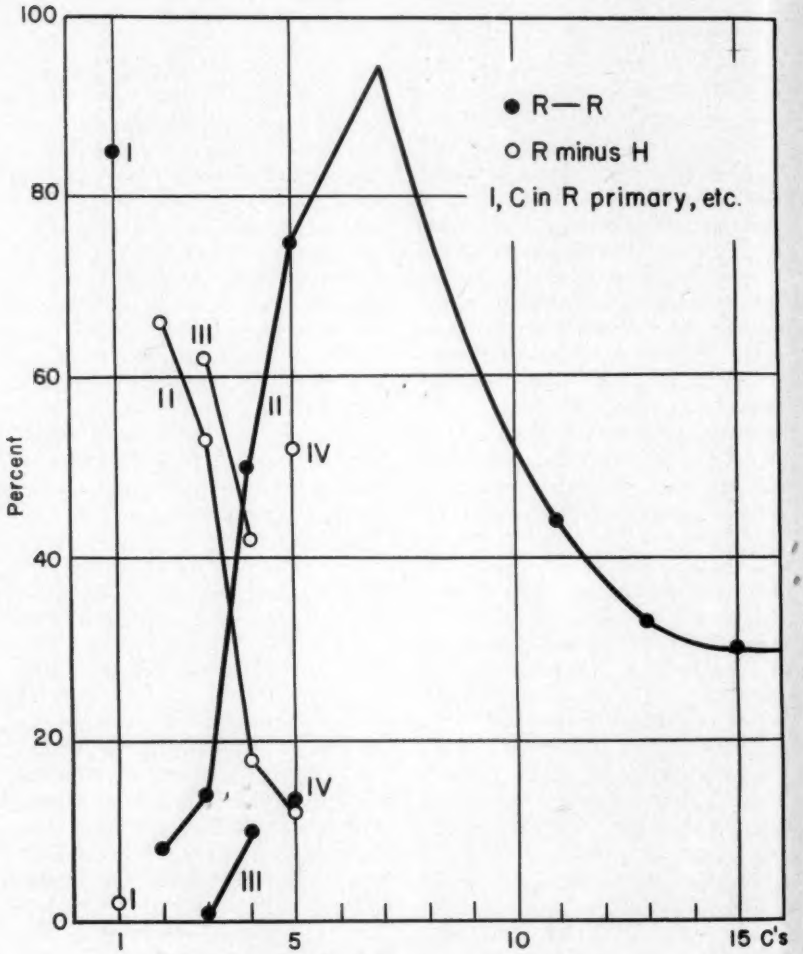

FIG. 1.—Current yields vs. number of C's in R.

the first U tube removes the CO_2. All the stable products have even numbers of electrons.

(f) The loss of H atoms from some of the CH_3 radicals. Since each H atom carries an electron, this leaves the new CH_2 radical with an even number of electrons, so it is a reaction which should tend to occur. The methylene dimerizes to C_2H_4, which is removed from the ethane by the H_2SO_4 in the second U tube.

It is also helpful to visualize this electrolysis of acetic acid in relation to two very familiar pyrolyses of the same substance. Thus,

(a) acetate ion + alkali ion + thermal energy → methane + carbonate.

(b) acetate ion + alkali ion + electrical energy → ethane + carbon dioxide + hydroxide ion (formed at cathode when H_2 is liberated).

(c) acetate ion + alkaline-earth ion + thermal energy → acetone + carbonate.

Since, of course, the carbonate or hydroxide can be converted to the starting salt by adding more acetic acid, with evolution of CO_2 if the carbonate was formed, all three processes are decarboxylations of acetic acid; and the effect of the different metals, together with the directive action of the electrical field, may be compared as a study in catalysis.

Further, the Kolbe synthesis is the basis of interesting speculation. By analogy to the first example, R · COOK should yield R · R abundantly, whatever the nature of R·, with a little (R minus H), ROH, and R · COO · R. This is not true. Even when R contains nothing but C and H, and is saturated, the proportions of the products are highly variable. Thus, potassium propionate yields very little n-butane, but produces ethylene (R minus H) copiously. As the homologous series is pursued, results intermediate between these two extremes appear. This is shown graphically in figure 1, in which the number of carbon atoms in R is plotted against percent current[3] yield. (The data here plotted are taken from table VIII, p. 43 of item (2) of the bibliography.) Solid circles designate R · R; open circles (R minus H). The roman numbers designate the type of carbon atom attached to the carboxyl group. In acetic acid, it is primary (I), being attached to only one other carbon. In the straight-chain acids propionic to stearic,[4] it is secondary (II). For this series most data were available. Only a pair of tertiary acids were tabulated, and only one quaternary. The following generalizations can be deduced from figure 1:

(a) The yield of R · R is an inverse function of the yield of (R minus H).

(b) The type of carbon atom attached to the carboxyl determines the family to which an acid belongs in this synthesis.

(c) The extra CH_2 group acquired in converting a secondary carbon atom to a tertiary does not greatly alter the yield, since curves III could nearly be superimposed on curves II by shifting the abscissa one unit to the left.

(d) The maximum yield of R · R might be expected in about the

[3] The current yield is chosen rather than the material yield because it is more easily defined. This is because the cathode action forms ions equivalent to KOH in its vicinity, and the solution tends to become alkaline as electrolysis progresses; and when the hydroxide ion concentration reaches the anode, hydroxide discharges ever more readily and production of $CH_3.COO$ radicals falls off. To prevent this, excess of the free acid whose potassium salt is being electrolyzed is maintained in the system.

[4] Off the scale of figure 1, but on the curve.

region of octanoic acid, where the data fail.

(e) Acetic acid is an isolated, rather than a typical, case.

(f) The production of (R minus H) is about as typical as the production of R · R.

More speculation may be centered about the role of unsaturation in this synthesis. As a product, it is common. When it is initially present, it inhibits the synthesis. It does this by raising the discharge potential of the organic anion, making it relatively easier to discharge hydroxyl. Straight-chain double bonds, if nearer to the carboxyl than the delta atom, usually prevent the synthesis from occurring. Benzenoid double bonds have a similar action. Fichter and Stenzl used pyridine, alone or with methyl alcohol, as a solvent for this synthesis, and thus provided solvent anions much more difficult to discharge than hydroxyl. In these solvents they were able to convert benzoic acid to diphenyl, and phenylacetic acid to dibenzyl.

It is interesting to note that some 4-phenylpyridine was recovered in the electrolysis of benzoate in pyridine. This is for this system analogous to ROH in water, and suggests that pyridine ionizes by disengaging a hydrogen atom at the point most remote from the nitrogen, and that if other ions are also produced, this is the one most easily discharged. As a rough approximation, unsaturation is a fairly typical product; its initial presence operates against the formation of more, according to Le Chatelier's theorem.

Since the ethylenic double bond is a ring system of two atoms, the behavior of larger ring systems is of interest. Such systems with three, four, and five carbon atoms in the ring, and the ring adjacent to the carboxyl group, have been investigated. Only R · COO · R and ROH seem to evolve in significant amounts. This suggests: (a) the organic discharge potential is somewhat raised, so that it is about comparable to that of hydroxide, so that liberal amounts of both R · COO and OH are present together; (b) the rate of decomposition of R · COO into R and CO_2 is lowered, so that considerable R and R · COO exist together.

Finally, the synthesis offers a wide field for investigation. Decomposition potentials, material yields, and gas analyses are largely unrecorded, except for the first three members. Other solvents besides pyridine, methyl alcohol, and water might be investigated. The effect of the alicyclic ring more remote from the carboxyl appears to be unknown. The effects of temperatures and pressures much greater than atmospheric have not been studied. Much may possibly be done by a careful literature search; the earliest work is so old that copies or direct abstracts of it are not available in the smaller chemical libraries. For many experimental studies no especially difficult apparatuses or techniques are needed. A study of the electrolysis of mandelate ion, $C_6H_5 \cdot CHOH \cdot COO^-$, is offered as an example. Since this is a substituted acid, it might be well to note these recorded results for such; R is listed:

(a) Forms R · R · abundantly: acetyl, o-nitrophenyl.

(b) Forms (R minus H) abundantly: α-hydroxy ethyl, α-hydroxy proply, β-hydroxy propyl, ∂-gluconyl, allo-camphoryl, phenyl hydroxy methyl (which is the R of the mandelate ion).

The case of R being $C_6H_5 \cdot CHOH$ was investigated by Walker in 1896,

using an aqueous solution.[5] He records the production of only small amounts of hydrobenzoin $C_6H_5 \cdot CHOH \cdot CHOH \cdot C_6H_5$, but a considerable amount of benzaldehyde, C_6H_5CHO. Since the former is the RR product and the latter is (R minus H), it is evident that mandelic acid, $C_6H_5 \cdot CHOH \cdot COOH$, resembles propionic acid rather than acetic acid in regard to behavior of its ion in a Kolbe electrolysis. Walker suspected that the hydrobenzoin resulted from the cathodic reduction of the benzaldehyde. It is, of course, possible to take the converse view and assume that the benzaldehyde results from the anodic oxidation of the hydrobenzoin. Oxygen thus used would come from discharged hydroxyl ions from the solvent water. This proposition was tested by using the technique of Fichter and Stenzl to electrolyze the mandelate ion in non-aqueous solvent. The potassium salt in methanol-pyridine, and the diethylammonium salt in pure pyridine, were both tried.

An undivided cell was used. A small copper beaker held the electrolytic solution and served as a cathode. A platinum anode was supported by a glass tube led through a three-hole rubber stopper into the cell. Gas was led to a Burrell analyzer from a tube inserted in another bore of the stopper. The temperature of the mixture was maintained at 24°C. by external cooling with ice water. A typical reaction mixture was 51 ml. of 1 N. methanolic potassium hydroxide, 38 gms. of mandelic acid, and 51 ml. of pyridine. About 40 volts were used to maintain about 0.7 amperes of current. When a gas analysis was not desired, a larger electrolysis vessel, consisting of a 400 ml. tall-form beaker, was used. A spiral copper tube carrying water was the cathode, and a rotating platinum spiral was the anode. Coulombs would be passed in excess of the theoretically required amount. Several runs from the large cell would be combined for isolation of the organic products, by usual techniques, substantially as outlined by Fichter and Stenzl. Again much benzaldehyde was found, and very little hydrobenzoin. That some of the latter was present was proved by the precipitation of silver iodate from a solution of silver ions and periodic acid, a test quite specific for 1, 2 dialcohols. Moreover, by working up the material from the proper point in the organic separation scheme, a small amount of substance was prepared by reaction with benzoyl chloride, which gave the proper melting point for the dibenzoate of hydrobenzoin. Since pyridine alone gave no appreciable amount of hydrobenzoin, and since pyridine could not possibly release anode oxygen since it contains none, it could not be argued that the benzaldehyde resulted from the oxidation of the hydrobenzoin. Rather, the prime stable compound formed from the free radicals was of the (R minus H) type.

The average of several gas-analysis experiments was expressed as a ratio of H_2 to CO_2 equal to 0.8, the individual values varying from 0.763 to 1.075. Remembering that both cathodic and anodic H_2 is registered and that 2 faradays make 1 gram-molecular volume of cathodic hydrogen and 2 g.m.v. of anodic CO_2, we see that this ratio should be

[5] It is surprising that $C_6H_5 \cdot CHOH \cdot COO^-$ ion discharges in aqueous electrolysis, since $C_6H_5 \cdot CH_2 \cdot COO^-$ does not. Apparently, although the double bonds in the molecule tighten the terminal electron, the hydroxyl oxygen loosens it.

0.500 for a perfect RR synthesis; but if each radical that furnished a CO_2 furnished addionally $\frac{1}{2}H_2$, the ratio should be 1.00. Also, any discharge of solvent anions would increase this ratio by cutting down its denominator more extensively than the numerator. The picture supported by the gas analysis therefore is that of extensive (R minus H) synthesis, accompanied by some R · R formation.

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A SPHERICAL ARRANGEMENT OF THE CHEMICAL ELEMENTS*

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Chemical literature includes many periodic tables, charts, or other means of classifying the chemical elements. Some have involved a great deal of work. Others may not have been so laboriously prepared. But the purpose in them all has been to establish a satisfactory correlation of chemical knowledge as related to the physical and chemical properties of the elements.

A study of these various periodic arrangements will show common failings to be either that of placing different elements on the same position in the chart or placing a group of elements outside the chart, as is commonly done with the rare earths.

A few authors have attempted to overcome these difficulties. The spherical arrangement suggested by Friend (1) and the helical form proposed by Harkins (2) are outstanding. We have found, however, that a more desirable organization is obtained by using both helical and spherical arrangements together in the same system.

This arrangement is outlined below and takes the form of a sphere. The upper hemisphere includes most of the known elements. Only a few elements at the begining of the lower hemisphere are known, and thus it is largely theoretical and extrapolated on the basis of the following reasonable assumptions.

Assumptions.—The two assumptions on which the construction of the complete sphere is based are: first, that the actinide series, when completed, will resemble the lanthanide series (3); and second, that the pattern outlined in the upper hemisphere of the system will repeat itself, decreasing the way it built up, to an end. Here a hypothetical element with an atomic number of 172 would come in as the last element. This element would have an electronic configuration of: 2, 8, 8, 18, 18, 32, 32, 18, 18, 8, 8, 2. The equator of the sphere would arbitrarily come between the sixth and seventh periods.

The pattern.—The following description outlines the organization of the complete sphere, including both the top hemisphere containing the known elements and the extrapolated theoretical lower hemisphere.

The sphere is divided into twelve latitudes, six in each hemisphere. The first seven latitudes compose the seven known periods, the seventh being incomplete at present. The remaining five latitudes are theoretical and serve to complete the pattern on the sphere. There are eight longitudinal bands (groups), two of which originate and terminate in the first and last latitudes; these are groups I and VIII (the inert gases).[1]

* Presented before the Chemistry Section of the Illinois Academy of Science at Galesburg, May 6, 1949.

[1] Since the elements in the various groups hold group numbers corresponding to the number of electrons in their outermost shell, it seems reasonable to label the inert gas group as group VIII, for helium is the only inert gas without eight electrons in its outermost shell, having but two electrons; this eliminates the designation "zero." For simplicity, the nine elements of the so-called group VIII may be designated the "Triad System," of group VIIIB, for they lie between groups VIII and I, are not inert, and range in valence from one to eight. If C and D groups were attached to the triads, it would indicate that they are inert elements; and, of course, group VIII is the only group that can have inert elements in it.

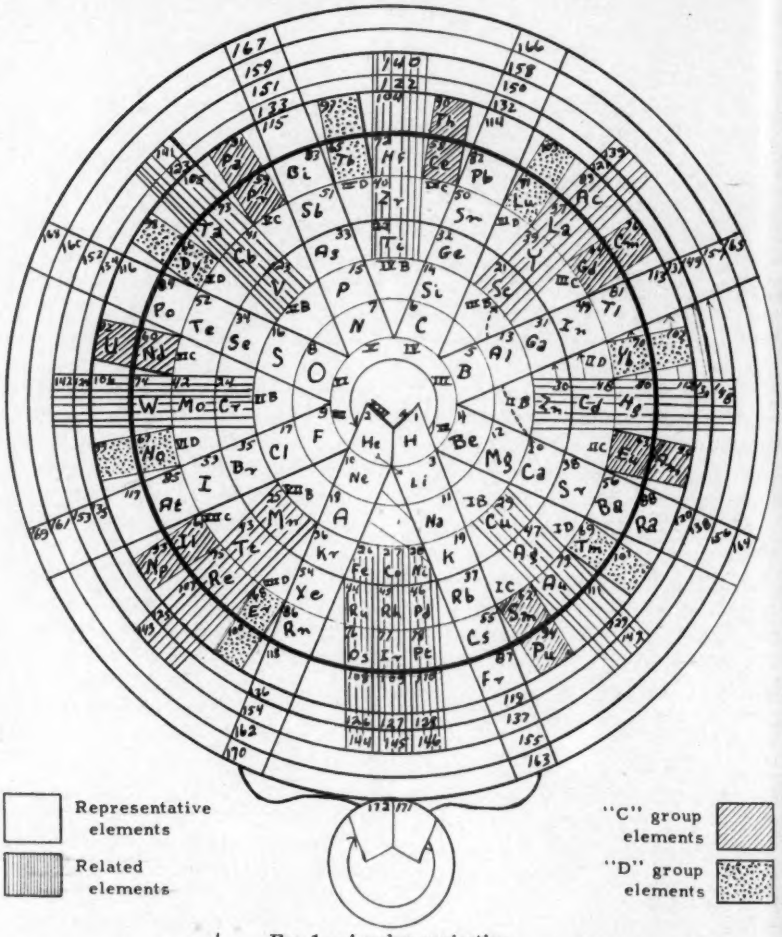

FIG. 1.—A polar projection.

The other groups originate and terminate in the second and eleventh latitudes. These eight longitudinal bands comprise the eight groups of representative elements. Group I, which cuts twelve latitudes, is immediately followed by groups II through VII, which cut ten latitudes, and then group VIII, which cuts twelve latitudes, as the first group. Between the eight main groups lie the ten B groups, originating in the fourth and ending in the ninth latitude, B groups eight, nine, and ten forming the triad system and lying between the main groups VIII and I. In each case the B group is placed after the main group to which it is related. Attached to the B groups (with the exception of the triad system) will be found the C and D groups on the left and right, respectively. These short groups, C and D, start in the sixth latitude and

end in the seventh latitude, the latitudes on either side of the "equator." Each period has its beginning in group I with the elements placed in a counterclockwise order. The last element in each period is found in group VIII, with the inert gases.

The elements with atomic numbers 21 through 30, inclusive, might be thought of as the calcium series, since it is from that element in period four that there is the deviation into the B groups, even as the elements deviating from lanthanum are known as the lanthanide series. The rare earth elements fill the C and D groups of the sixth period. Going backwards one element from lanthanum, one finds barium, from which the twenty-four succeeding elements deviate from the main group. Hence, this could be considered the barium series, which would be composed of the lanthanide series and the ten elements in the B groups that are part of this period. The deviations in latitudes six and seven are the same, and the deviations in latitudes, or periods, four, five, eight, and nine would be the same.

The transition points.—The system starts with hydrogen in group I, period (and latitude) one, and rotates counterclockwise until it reaches helium, the first inert element and the end of the first period. From the end of a period the transition is consistently to the element in group I in the next lower latitude. When period four is reached, the transition is not so simple, involving a total of five types of transition points.

The first transition point is from helium to lithium, period one to period two. The second and third transition points are the connections between the representative elements and the related elements of group A and group B. In period four, group II is the first transition point of this type: from calcium to scandium, and returning to the main groups from zinc to gallium. Once transition is made into the B groups from the representative elements, only the B groups are touched in the counterclockwise rotation until group IIB is reached, where the normal transition is to the main group III and the period is completed with an inert gas. The fact that an element is in a B group would indicate inner building in the second from the outermost shell. (See fig. 2, cross-cut view of period five.) These transition points are involved in periods four through nine, inclusive.

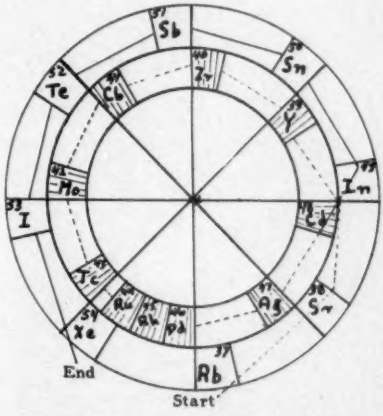

FIG. 2.—Period five, cross-cut view.

However, the transition points previously mentioned, although they apply to periods six and seven, become a little more complex with the introduction of transition points four and five. These transition points involve the departure from the B groups in group IIIB, period six, and the return from IIID to IVB. To illustrate: from lanthanum (IIIB, period six) to cerium (IVC,

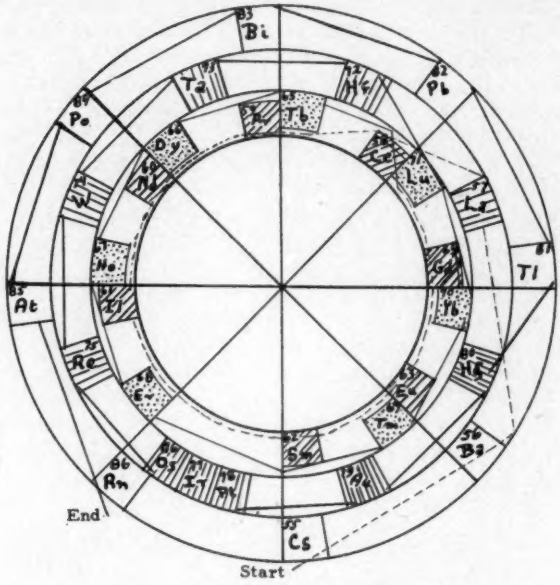

FIG. 3.—Period six, cross-cut view.

period six), and from lutecium (IIID, period six) to hafnium (IVB, period six). It is pointed out here that the transition from gadolinium (IIIC, period six) to terbium (IVD, period six) is not considered a transition point, since it is merely completing the lanthanide series. (See fig. 3.)

The fourth and fifth transition points form a system similar to the transition system involving the B groups, except that this group of the elements, C and D groups, gain electrons in the third from the outer shell. The last element in the lanthanide series ends with element number 71, and this element is in IIID, where both C and D groups are filled. The building in the third from the outermost shell is almost completed in this element. Next the B groups are filled and finally the main groups. Period seven, just across the equator of the system, is assumed to be similar to the sixth period. From period seven to twelve, the number of elements in each period decreases in the same manner in which they reach the maximum. The transition points of all periods of the same length are the same throughout the entire system.

Theoretical basis for the treatment of the lanthanides.—A certain degree of periodicity in valence is found when the lanthanides are plotted as they are in figure 4. This is in agreement with the periodicity brought out by Moeller's (4) atomic volume plot of the lanthanides, and in Van Rysselberghe's "New Periodic Table" (5). The circled valences in figure 4 indicate valence states either of minor importance or of those unobtainable in the presence

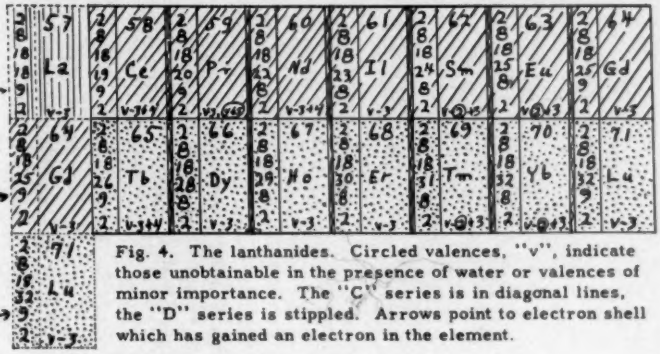

Fig. 4. The lanthanides. Circled valences, "v", indicate those unobtainable in the presence of water or valences of minor importance. The "C" series is in diagonal lines, the "D" series is stippled. Arrows point to electron shell which has gained an electron in the element.

FIG. 4.—The lanthanides.

of water. These pairs of lanthanides were attached as C and D groups to the B groups in period six, excluding the triad system. Their variance in valence is generally similar to that of the B group to which they were attached; this is part of the basis for attachment to the B groups. The lanthanides are thus included in period six, which has 32 elements. Position in the C and D groups shows relation to the B groups and more or less remote relationship to the elements in the main groups.

Attention is called to gadolinium and lutecium, attached to lanthanum, because they gain an electron in the second from the outermost shell as does lanthanum. Lutecium is more closely related and similar to lanthanum because of the fact that its third shell is complete like that of lanthanum (6).

A letter in *Nature* (7) points out that divalent compounds of both europium and ytterbium exhibit a strong blue fluorescence when exposed to ultra-violet light; these elements are attached to group IIB in period six and are one of the pairs formed in figure 4.

Theoretical basis for the treatment of the actinides.—Certain of the actinides, attached immediately below the lanthanides and on the opposite side of the equator of the spherical system, have for some time been considered as properly belonging to the B groups of the related elements (8). For example, thorium has been considered to belong to group IVB. In the spherical system this element is appropriately attached in a C group, maintaining its relationship to group IV, and also in accord with the modern concept of thorium as part of the actinide series (9). This same relationship is observed in the case of protactinium, in group VC, and of uranium, in VIC, which are attached to their respective B groups.

The lanthanides and actinides are thus attached to the B groups in such a way that their relationship to the other elements is evident, and yet their individuality is retained by their placement in C and D groups.

Interpretation of the diagrams.—Figure 1 is a polar projection of the sphere. A study of it will show that the equator of the system lies between periods six and seven. The

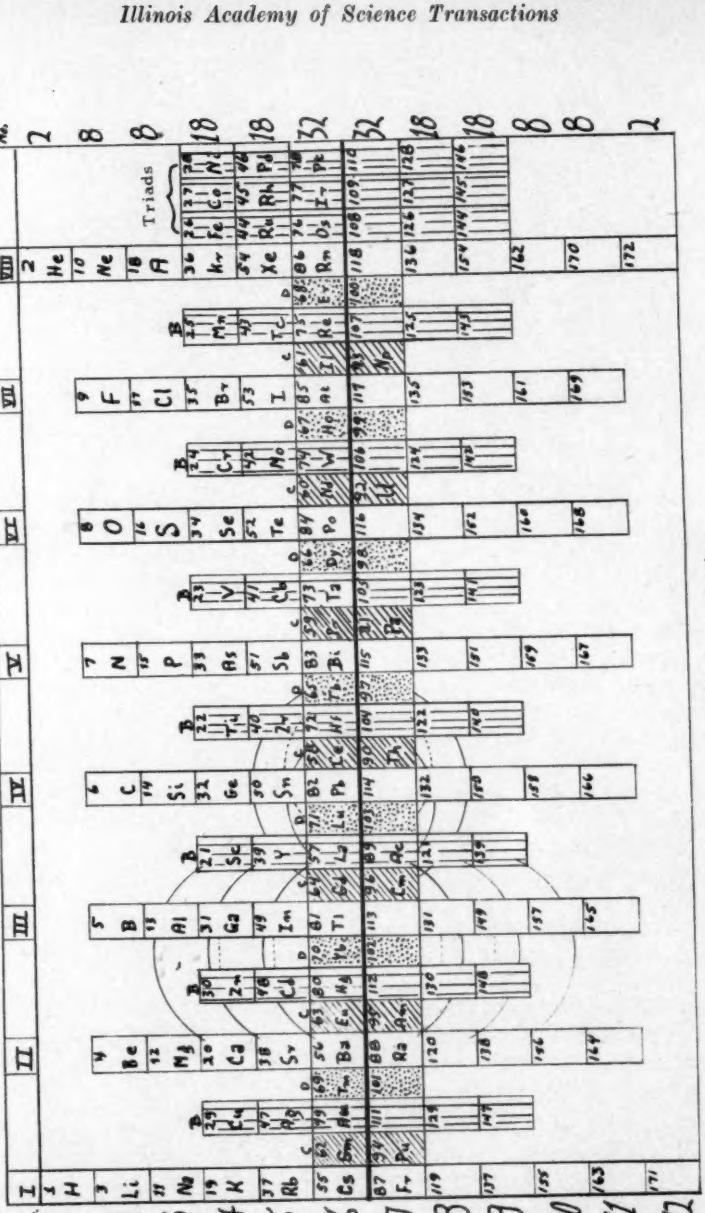

FIG. 5.—A Mercator projection.

pattern of the lower hemisphere is extended in a manner similar to the way in which the upper hemisphere built up to period six with its 32 elements, but in reverse: starting with the seventh period filling out to 32 elements and the following periods having 18, 18, 8, 8, and 2 elements. The key is the same in all the diagrams. A white background denotes the representative or main elements (A groups). A vertically lined background denotes the related elements (B groups), and slant-lined and stippled backgrounds denote the C and D series respectively of the "rare" elements, the lanthanide and actinide series. The heavy black line indicates the equator of the system. In figure 1, the theoretical, extrapolated periods eight, nine, ten, and eleven are reduced in size so that they may be included.

Figure 2 gives a cross-cut view of period five, and figure 3 of period six. These two diagrams show how the elements build up in the spherical system, and suggest analogous positions of electrons in the particular latitude of electrons building up.

Figure 4 shows the periodicity in the lanthanides in regard to valence; and the electrons in the various shells as well as the valence states are included in the diagram. Figure 5 is a Mercator projection of the spherical system.

Advantages.—a. The number of elements in each period is easily ascertained, since it is known that the periods contain respectively 2, 8, 8, 18, 18, and 32 elements.

b. The inert gases, elements which have all their electron shells filled, are placed at the end of their respective periods.

c. The representative elements, those with all but the outer shell filled, stand out clearly.

d. The related, or B group, elements are placed adjacent to and following the group to which they are related.

e. The "rare" elements, the lanthanide and actinide series, are placed in C and D groups showing three incomplete electron shells and showing their relation to the B group elements and through these to the representative elements. Elements in B groups show building in the second from the outer shell, and those in C and D groups show building in the third from the outer shell.

f. Interpretation of the periodicity of the elements, in terms of electronic configuration, is greatly facilitated, position in the sphere being directly related to electronic configuration.

g. Erroneous analogies between A and B group elements are avoided, and family relationships are clearly emphasized.

h. Elements of any specific group retain their distinctive characteristics, and at the same time show their relationship to the other elements in the group, as B, C, and D group elements.

i. The lanthanide series is included in the system in a satisfactory way, and its relation to the other elements and the periodic table is clearly shown.

j. There is a logical continuity within the system.

Summary.—A new arrangement of the atoms is described which has a combined helical and spherical organization. The system incorporates the representative, the related, and the rare earth elements in one sequence and in correct relationships to the other atoms. A theory concerning the electronic configuration of the undiscovered elements is presented.

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GEOGRAPHY

GEOGRAPHICAL POSSIBILITIES OF CORK PRODUCTION IN THE UNITED STATES

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Scattered cork oaks growing in southern and southwestern states may prove to be the forerunners of an important cork production industry in the United States. The cork oak is indigenous to the Mediterranean region, the present center of world cork production, and trees from that region have been introduced into the United States. They represent various spasmodic attempts by the government, educational institutions, and interested individuals to establish the cork oak in this country.

Need for Cork

The need for cork in American industry was shown when the War Production Board listed it as one of fifteen critical materials essential to keeping the wheels of production turning. Even before the attack on Pearl Harbor, American supplies of cork were placed under strict regulation to channel them into defense and essential civilian usage. Cork gaskets and washers are "must" parts in keeping grease and oil at work lubricating machines. Among other uses of cork are insulation, corkboard, bomb parts, submarine linings, and life preservers.

> Cork is one of those versatile natural materials, like leather, that can do a lot of jobs well, and for which there is no single acceptable substitute . . . . The freeing of North Africa, and the bettering of the shipping situation to Mediterranean ports on the European side have relieved the cork situation considerably. Nevertheless, our recent unpleasant experience has taught us a sharp lesson and it will be far better, no matter what kind of improved world the peace may usher in, not to leave ourselves in a position to be caught in the same fix again.[1]

The exigencies of the early years of World War II plainly showed that cork production in the United States would be economically desirable if it could be proved geographically possible.

Present Distribution

The world cork supply comes from a region about the size of New Jersey. This region of intensive production lies within an area stretching for more than 1000 miles along the western part of the North African coast. In Europe the region stretches from the Landes area of France around the Iberian Peninsula in a narrow fringe along the Mediterranean to the toe of the Italian boot. Figure 1 shows the location of the Mediterranean region cork producing areas, for which the 1936 production statistics are given in table 1. This is the latest year for which full statistics for all countries are available. Incomplete figures for 1941 show small increases in production, but the only available postwar information indicates a small reduction following wartime peaks in Portugal and Spain.[2]

[1] Frank Thone, "Cork in Bottleneck," *Science News Letter*, XLIV (October 16, 1943), p. 247.
[2] Private communication with Spanish and Portuguese Embassies.

TABLE 1.—CORK OAK ACREAGE AND CORK PRODUCTION, MEDITERRANEAN REGION—1936[3]

Area		Country	Annual Production		
% of total	Acres (000's)		Short tons (000's)	% of total	Yield lb./acre
33.8	1,720	Portugal	130.0	46.2	151
12.2	622	Spain	66.0	23.1	212
21.6	1,100	Algeria	38.5	13.8	70
14.6	741	French Morocco	17.6	6.3	48
6.9	350	France, Corsica	13.2	4.8	75
4.9	247	Italy, Sardinia, Sicily	8.8	3.2	71
4.6	235	Tunisia	7.4	2.6	63
1.4	74	Spanish Morocco*	.....	.....	.....
100.0	5,089	Mediterranean Region	281.5	100.0	112

* Included as a potential producer.

GEOGRAPHIC FACTORS IN CORK GROWTH

The geographical possibilities of cork production in the United States are intimately related to temperature, rainfall, and soil. It was found that the cork oak grows: (1) equatorward of a composite line based on the 37° F. January and the 50° F. annual surface isotherms; (2) at annual surface temperatures between the limits of 50° F. and 70° F.; (3) under an annual rainfall between the limits of 10 and 60 inches; and (4) in a variety of soils ranging from semi-arid brown steppe soils to the moist tropical and subtropical red and yellow soils.

To translate these facts to the American scene, a map was constructed, showing the portion of the United States which met the above qualifications. Figure 2 shows this area, plus the areas too dry, too wet, or too hot. The unruled section of the United States lies beyond the poleward limit of growth for the cork oak.

[3] Victor A. Ryan, *Some Geographic and Economic Aspects of the Cork Oak* (Baltimore: Crown Cork & Seal Co., Inc., 1948), p. 19.

DISTRIBUTION OF AMERICAN CORK OAKS

With this picture of climatic and soil factors, our attention can be directed to the introduction and spread of the cork oak in the United States. Thomas Jefferson seems to have been the first American interested in the cork oak, but his attempts at establishing a cork production industry proved futile. The government was successful in 1858 and again in the eighties in having a few trees survive in the southeastern states and California. A substantial planting at Chico, California, was made in 1904, and state and local plantings have resulted in a distribution of cork oaks in the United States as shown in figure 3. It is interesting to note that they are not limited to the area usually classified as typically Mediterranean.

In 1940, over five tons of bark were stripped from California trees, marking the first time that cork oaks outside the Mediterranean region had been stripped of commercially marketable cork. Tests by the Crown Cork and Seal Company of Baltimore showed this bark to be equal

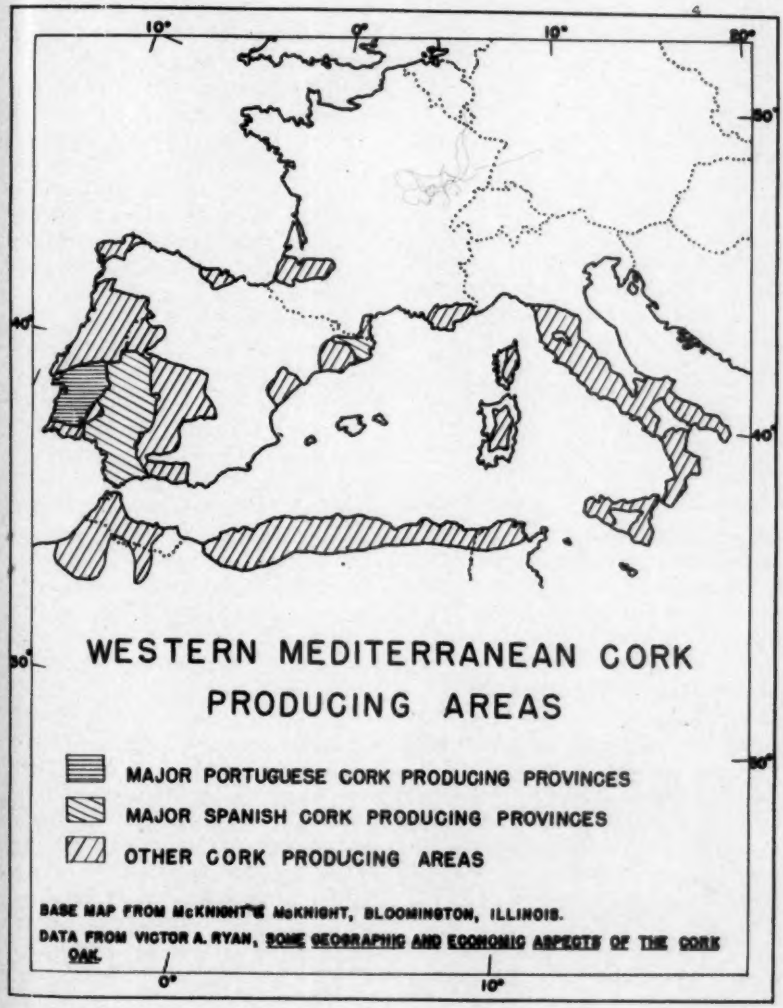
10°
0°
10°
20°
50°
40°
40°
30°
30°
WESTERN MEDITERRANEAN CORK PRODUCING AREAS
MAJOR PORTUGUESE CORK PRODUCING PROVINCES
MAJOR SPANISH CORK PRODUCING PROVINCES
OTHER CORK PRODUCING AREAS
BASE MAP FROM McKNIGHT'S McKNIGHT, BLOOMINGTON, ILLINOIS.
DATA FROM VICTOR A. RYAN, SOME GEOGRAPHIC AND ECONOMIC ASPECTS OF THE CORK OAK.
0°
10°

FIG. 1.

in quality to Old World cork. When considering that the United States imports some 150,000 tons of cork annually, it is readily seen that it was the *fact* rather than the *amount* of production that was of chief significance.

Production and Marketing Problems

In order to develop an overview of the industry, we may turn our attention to how the industry is conducted, what marketing practices may be developed, what competition in land use may be encountered, how competition by other products and by foreign countries is met, and what other problems cork producers may face.

Conduct of Industry

Cork production is a forest industry, the commercial product, cork, being the outer layer of the *Quercus suber* and *Quercus suber occidentalis* species of evergreen oak. The inner layer of bark, or phellogen, is alive and acts as a base on which each year the tree adds a new layer of cork. As these succeeding new inner layers are added, the outermost layers cease to be a living part of the tree and serve only as an insulating wrapper protecting the tree against loss of moisture and against the hot winds known as siroccos in the Western Mediterranean region.

It has apparently been known since Greco-Roman times that this outer bark could be removed without injury to the tree. The process of bark removal is known as stripping, and the same methods are being used in the United States that have been successful in Europe and North Africa. Two cuts are made around the tree with a sharp two-bladed hatchet, one cut at the ground level and the other just below the main branches (or at the height prescribed by law in most of the Old World cork-producing countries). Two vertical cuts following natural crevices in the bark are made, joining the horizontal cuts. The wedge-shaped hatchet handle is then inserted under the loosened bark and the whole sheet is pried off. The larger lower branches may be stripped in the same manner. Care must be taken not to injure the inner bark, and stripping should not be undertaken while a hot wind is blowing as the newly exposed phellogen will be dried out too rapidly. Nevertheless, the middle of the summer is the accepted stripping season.

The first stripping produces cork with a rough, grayish, uneven surface, known in the United States as "virgin" cork, suitable only for grinding for cork insulation and cork composition products. The second stripping is considerably better and, with the third stripping, fine quality cork is obtained. The trees are first stripped when 15-20 years of age and every 9-12 years thereafter during the productive life of about 100 years. The stripped bark is piled and allowed to dry a few days in the forest. It is then ready for boiling, a process which softens the cork and increases its elasticity so that it can be flattened for baling. Boiling removes dirt, sap, and tannic acid, and also softens the useless woody outer layer which is scraped off. The cork is dried, roughly sorted according to quality, and baled, ready to be taken from the immediate area of production.

Marketing Practices

American cork production has been so limited and so intimately

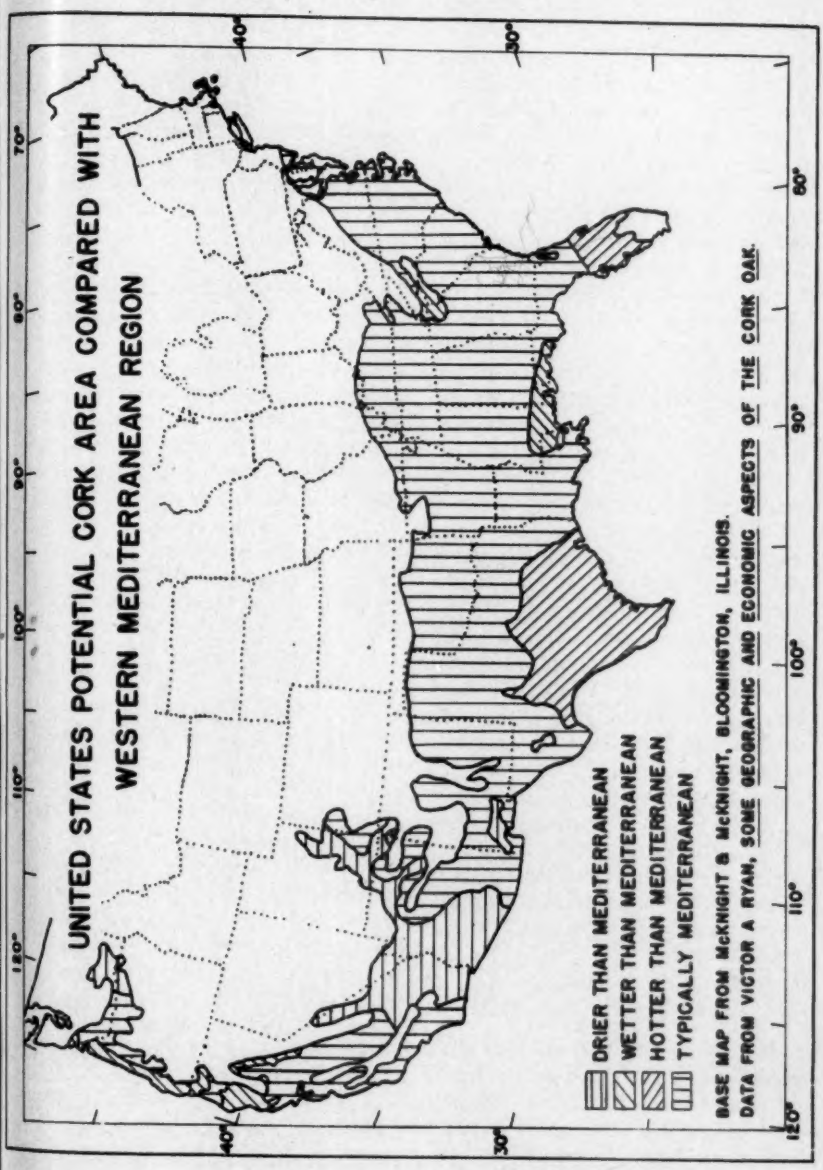
UNITED STATES POTENTIAL CORK AREA COMPARED WITH
WESTERN MEDITERRANEAN REGION
DRIER THAN MEDITERRANEAN
WETTER THAN MEDITERRANEAN
HOTTER THAN MEDITERRANEAN
TYPICALLY MEDITERRANEAN
BASE MAP FROM McKNIGHT & McKNIGHT, BLOOMINGTON, ILLINOIS.
DATA FROM VICTOR A RYAN, SOME GEOGRAPHIC AND ECONOMIC ASPECTS OF THE CORK OAK.
120°
110°
100°
90°
80°
70°
60°
50°
40°
30°

FIG. 2.

connected with the cork manufacturers that a definite code of competitive marketing practices has not as yet been established in the United States. In order to see what may develop here, an examination of two marketing systems employed in the Mediterranean region follows.

By one method the buyer purchases the cork bark in the forest before stripping. Before purchasing, the buyer sends a sampler through the forest who removes a small cylindrical section of cork from representative trees much as a fruit dealer plugs watermelons. These discs are taken to the buyer's office for careful examination before the buyer makes a bid to the forest owner.

The second method involves the sale of the stripped cork bark at public auctions. Some of these sales are handled in a manner similar to American auctions, while others have the unique feature of starting at a high figure, the auctioneer gradually lowering the asking price until a bid is received. The first lots of cork offered are generally small, and are frequently purchased by small operators before the large buyers come in and take everything.[4]

It should be re-emphasized that American cork production has been so limited to this time that neither the above nor other marketing practices have been developed in the United States.

Competition in Land Use

The study of soils revealed that Mediterranean cork was produced on relatively poor soils, the leached subtropical and tropical reds and yellows, and the brown steppe with its alkaline accumulations frequently forming a hardpan layer in the soil. In the United States, desert soils are supporting many mature cork oaks. Thus it is evident that the cork oak will thrive upon soils in which other vegetation is sparse. The United States contains hundreds of thousands of acres of the above mentioned soil types that could be planted to cork oak without crowding out or even infringing upon other economies. Many of the recent plantings in America have been made along fence rows, roadways, and in pasturelands. Few of the cork oak forests in the Mediterranean region are pure stands. The cork trees are often associated with olive trees, vineyards, or with other live oaks in pastures. Swine do very well feeding upon cork and other oak acorns. The pork of acorn-fed swine is said to have a very desirable piquant flavor. These concomitant land uses permit a sizable income per unit of land.

Competing Products

As mentioned in the opening paragraphs, no single acceptable substitute for cork has been found. Some of the materials used in place of cork are just as scarce as cork and are critically needed for other uses, as was found during World War II. Even for packing material, military technicians could find no successful substitute for cork. Materials such as pine needles and dried grasses were tried but none had all the qualities of cork—heat resistance, buoyancy, and strength. Barks of other trees, such as Pao Santo, Douglas fir, and other true firs have been studied and tested, but none has proved entirely satisfactory. To compete with natural cork in normal times, other barks must be cheaper, more readily accessible, or better than cork. At

[4] Arthur L. Faubel, *Cork and the American Cork Industry*, New York: Cork Institute of America, 1941, p. 16.

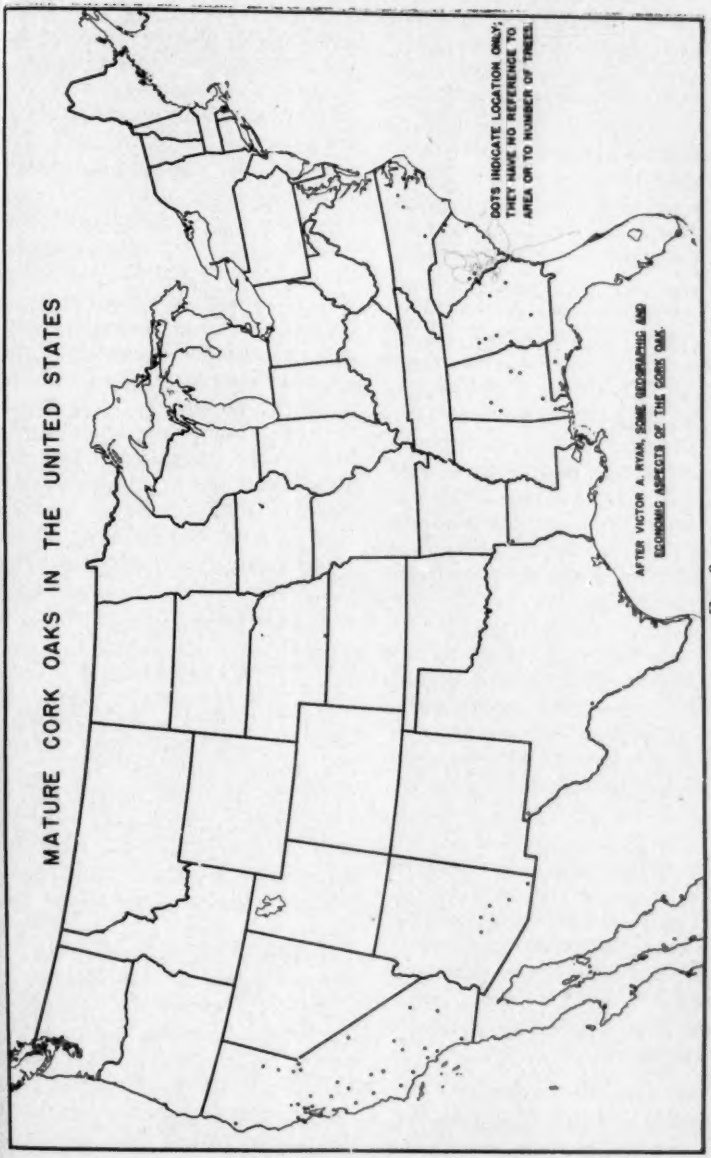
MATURE CORK OAKS IN THE UNITED STATES
DOTS INDICATE LOCATION ONLY; THEY HAVE NO REFERENCE TO AREA OR TO NUMBER OF TREES.
AFTER VICTOR A. RYAN, SOME GEOGRAPHIC AND ECONOMIC ASPECTS OF THE CORK OAK.

FIG. 3.

TABLE 2.—UNITED STATES IMPORTS OF UNMANUFACTURED CORK[5]
(Thousands of pounds)

Year	M Pounds
1927	223,091
1928	229,671
1929	267,598
1930	174,615
1931	135,401
1932	118,438
1933	187,184
1934	122,565
1935	153,076
1936	216,390
1937	322,898
1938	158,381
1939	227,575
1940	318,336
1944	189,629a
1945	265,453b

a From *Foreign Commerce and Navigation of the United States. Calendar Year 1944*, Vol. I, *Import and Export Statistics*, p. 199.
b *Ibid. Calendar Year 1945*, p. 133.

present they are none of these. Herman M. Kulman has patented a synthetic substitute made from peanut hulls.[6] It has been tested and judged acceptable for use in bottlecaps, gaskets, and wallboard, but is more expensive than natural cork.

The discussion of the other natural products and the synthetic material indicates that natural cork, to date, has been able to meet the competition of any and all substitute products. This is further borne out by the United States import statistics given in table 2. By 1945, United States imports of natural cork had again risen to a figure exceeded only by three peak pre-war years, indicating that very little, if any, of the United States demand is being filled by substitutes when natural cork is again available in large quantities.

FOREIGN COMPETITION

Since natural cork apparently can meet successfully the competition of substitute products, the competition faced by American producers will come from cork production abroad. There are at least two ways to meet this competition: one, with the aid of a protective tariff; and, two, by actually equalling or under-bidding the prices of Old World cork at the factory door. At present, unmanufactured cork is on our free trade list, and a protective duty seems unlikely and probably undesirable at this time. Victor A. Ryan's study showed that in terms of income per acre of cork oaks, based on actual American production costs and present Mediterranean prices, the American grower can compete with the Old World producer and deliver bark at the American factory door at a lower figure.[7] It would seem that a scientifically based American cork production industry should easily survive the competition of the Old World cork production industry as the latter is now being conducted.

OTHER PROBLEMS

Other problems that American cork producers must face are cork oak diseases and insect pests. As yet, only the cork oak cynipid has given trouble. This small insect has infested some California trees, killing smaller twigs, and reducing the vitality and bark growth in some instances.[8]

Another problem involves the rate of growth of the cork bark. Although it is known that xerophytes have no definite moisture requirements, being able to tolerate more moisture while continuing to grow slowly, there is some acceleration in the growth rate of cork due to in-

[6] Mary V. Day, "Cork Goes to War," *Foreign Commerce Weekly*, pp. 54, 58.
[6] "Peanut Hull Cork," *Business Week* (November 27, 1943), pp. 54, 58.

[7] Ryan, *op. cit.*, pp. 85-87.
[8] E. O. Essig, "The Cork Oak Cynipid in California," *Journal of Economic Entomology*, XXXVI (February, 1943), pp. 123-124.

creased precipitation. Since more rapid growth creates coarser structure and less valuable cork, the regions of the United States in the potential cork area wetter than the Mediterranean region are at a disadvantage compared to the drier American areas. They will lose more in price per ton of cork due to poorer quality than they will gain in weight by increased growth rates. On the other hand, trees in the wetter areas are larger producers of acorns, so important for planting in the establishment of any future cork production industry. Cultivation of the cork oak may increase the growth rate and imposes a problem as to the extent of cultivation economically desirable.

Conclusions

The United States has had a constant and fairly consistent need for cork, an especially critical essential material in wartime. The United States has within its borders vast areas having climate and soil characteristics similar to the present producing areas in the Mediterranean region; also it has other climatic regions in which cork trees are now growing. United States cork has been found equal in quality to Mediterranean cork. The estimated returns of American cork production conducted scientifically would seem to compare very favorably with Old World cork production income on an annual income per acre basis. A cork production industry in the United States could be established in addition to our present activities, with little or no infringement upon present use of productive lands; and there seem to be no technical problems or difficulties of consequence.

While the above facts may lead one to conclude that the establishment of a sizable cork production industry in the United States is inevitable, further studies will be necessary to test the application of theory to practice, and to interpret the effects that economic and political developments in the world have upon cork production. At this time we can only conclude that the United States seems to have the geographical possibilities for cork production, and reiterate the statement of J. Russell Smith, made in 1929, that "apparently there is no reason except inertia why we should not in time have an extensive cork (production) industry in the United States."[9]

[9] J. Russell Smith, *Tree Crops—A Permanent Agriculture.* (New York: Harcourt, Brace and Co., Inc., 1929), p. 139.

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WATER RESOURCE CONSERVATION IN ILLINOIS

H. E. HUDSON, JR.
State Water Survey, Urbana

In common with the rest of the United States, Illinois has been experiencing growth in population, with resulting greater density of population, larger communities, and increasing opportunities for the affairs of men to infringe on the affairs of other men. Thus the way we treat our resources comes to have an increasingly important effect on men, far greater than was the case a few decades ago.

With this increasing saturation of population has come development of a form of inertia, caused by the increasing growth of investment in business of every kind. A man now has a greater stake in his farm, in his factory, or in whatever enterprise he is engaged in. It takes more capital to start an enterprise, and this leads to higher overhead costs, so that men are much less amenable to changes in their way of doing things. This of course has led to regulation. Inevitably it will lead to increasing regulation in the field of resource development. If history repeats itself, we may expect the increasing regulation to come at times of stress such as periods of war or periods of depression. Thus we must give thought to the needs of the future at times when conditions are "normal."

General Situation

Figure 1 shows the principal sources of water supplies in Illinois. It will be noted that in a large part of southern Illinois, municipal water supplies are secured almost entirely from surface water sources, principally impounding reservoirs. Through the marginal drift area and through the minor rock well area, difficulty is noted in securing sufficient groundwater for municipal or industrial use.

There are exceptions to the above generalizations, where porous gravel deposits occur along streams or in buried bedrock valleys in these areas.

In general, groundwater levels throughout Illinois have not been seriously affected by works of man. In certain locations, there have been minor effects caused by drainage activities, by dredging channels, and to some extent by the increased cultivation of the land. A century ago, when little of Illinois was under cultivation and most of the soil was in prairie grasses, infiltration rates were high, and rates of penetration of rainfall into the earth were rapid.

With the changing trend of use of land to cultivated crops such as corn and soybeans, infiltration rates have been reduced. There has probably been some lowering of water tables owing to this change in land use, but no data are now available to measure the amount of the effect. The influence is probably relatively minor compared to the effects that are occurring in areas of large population, where heavy groundwater developments have taken place.

Groundwater

The occurrence of groundwater is determined by measuring water levels

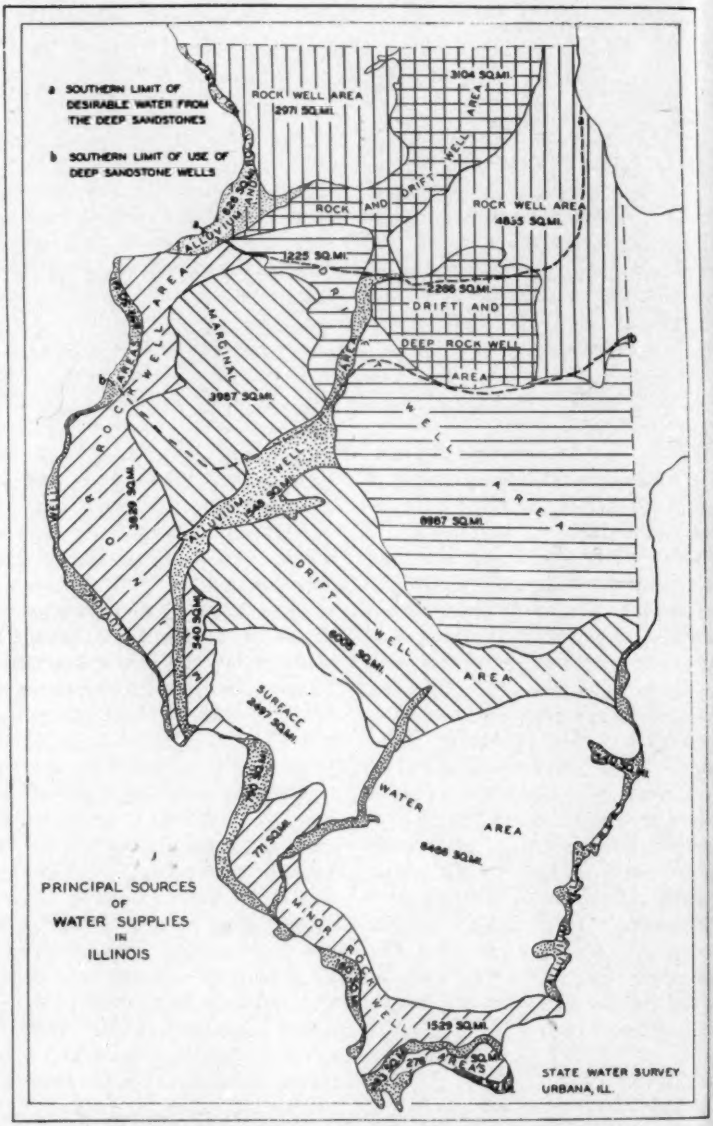
a SOUTHERN LIMIT OF DESIRABLE WATER FROM THE DEEP SANDSTONES
b SOUTHERN LIMIT OF USE OF DEEP SANDSTONE WELLS
ROCK WELL AREA 2971 SQ.MI.
3104 SQ.MI.
DRIFT WELL AREA
ROCK AND DRIFT WELL AREA
ROCK WELL AREA 4855 SQ.MI.
ALLUVIUM AND ROCK WELL AREA
1225 SQ.MI.
2206 SQ.MI.
DRIFT AND DEEP ROCK WELL AREA
MARGINAL ROCK WELL AREA
3987 SQ.MI.
ROCK WELL AREA
ALLUVIUM WELL AREA
8987 SQ.MI.
DRIFT WELL AREA
SURFACE WATER AREA
PRINCIPAL SOURCES OF WATER SUPPLIES IN ILLINOIS
STATE WATER SURVEY URBANA, ILL.

FIG. 1.—Principal sources of water supplies in Illinois.

in wells, by making pumping tests to observe the movement of those water levels, and by special chemical techniques to measure the movement of the waters and to identify their sources.

Recharge of groundwater from precipitation is a very slow business. With a comparatively few exceptions, it takes at best many months, and sometimes requires centuries. As Dr. Buswell, Chief of the Water Survey, has remarked, in some locations our best solution is to have prayed for rain 5,000 years ago. Groundwater data indicate that, over about four-fifths of the state, water can be secured in some quantity, but there are limits to the amounts that can be obtained at any given location.

Throughout northern Illinois it is possible to secure water in large quantities from wells drilled deep into the bedrock. In the east central part of Illinois, comparatively large volumes can be secured from wells drilled in the glacial drift. At many locations in the state there are limited deposits of sand and gravel that can yield sizable quantities of water, but these are difficult to locate and evaluate, requiring careful engineering study in each separate case.

For the most part our groundwater resources are healthy, unaffected by human activity. But at places where large concentrations of population have relied on groundwater, symptoms of trouble are appearing. These local problems have led many to suspect that groundwater resources over the whole state were failing. It is true that there have been difficulties at Chicago, Joliet, Rock Island, Peoria, East St. Louis, and Champaign-Urbana. Some of these local situations have become quite acute, most noticeable being that at Chicago, where water levels in deep wells are now as much as 500 feet lower than they once were. The lowering of water levels in heavily pumped areas affects less than five percent of the area of Illinois and, from the point of view of depletion of total water resources available in the state, it is not of great importance. Outside these areas of receding water levels there are large quantities of groundwater available which can be developed, although the costs of these new sources will be greater than the cost of the present groundwater development.

More than half the total population of Illinois is housed in the small portion of the state in which groundwater levels have been lowered by heavy extraction. These groundwater recessions therefore are of major importance to a large and vital section of Illinois' economy. The fact that the groundwater difficulties are limited in areal extent must not be allowed to obscure the influence of these effects on a major portion of the state's population.

TABLE 1.—INDUSTRIAL USE OF GROUNDWATER

Metropolitan area	Total use Mil. Gal./Day	Per capita use Gal./Day
Los Angeles, Calif.	360	124
Long Island, N. Y.	280	61
Houston, Texas	170	333
Memphis, Tenn.	105	316
San Antonio, Texas	100	313
E. St. Louis, Ill.	89	736
Peoria, Ill.	85	680
Philadelphia, Pa.–Camden, N. J.	85	29
Dayton, Ohio	85	313
Chicago, Ill.	84	21

Table 1 shows a summary of groundwater use in the 10 largest areas of industrial groundwater de-

velopment in the United States. It is interesting to note that three of these areas are located in Illinois: Chicago, Peoria, and East St. Louis. It is even more interesting to note that, of the 10 largest industrial groundwater developments (probably the largest 10 in the world), the two most intensive developments, when considered on a basis of the amount of water taken per person per day are East St. Louis and Peoria. Water is a major factor in industrial development, and it has been an extremely important factor in the growth of the state.

Surface Water

The rain that falls in the state and some that falls in our neighbor states, Indiana and Wisconsin, can travel three paths. It can evaporate; about two-thirds of it does. It can run off into streams; about one-third of it does. It could soak down into the earth to become part of our groundwater supply. Our best arithmetic indicates that only a very tiny fraction gets into the groundwater supply.

We measure the amount of surface water that occurs in Illinois through stream gaging installations operated by the ,U. S. Geological Survey office in Champaign. Another important part of the surface water study is the measuring of water quality, done by chemical analyses carried on in our laboratories.

Streams dry up at times and cannot be relied on to produce a dependable constant yield. Man therefore resorts to construction of impounding reservoirs to store water for the dry periods. Illinois has available approximately 600 useful reservoir sites. We have about 500 lakes and reservoirs. You can see that we have used a substantial proportion of the sites available; it is therefore of great importance that we use wisely those that remain. In the past, reservoirs have been constructed without full regard to soil and water relationships. Recent surveys indicate disturbing silting rates. We have come to realize that the conservation of soil is an essential to preservation of surface water resources. Unless we can succeed in keeping the topsoil on our farms, our society will come to an abrupt realization that the farms are no longer valuable, and the reservoir sites are full of sediment. Present data indicate that this may become a real problem during our children's lifetime.

If we are thrifty with our surface water resources, safeguarding them against silting and polluting, Illinois will have enough supply to support a population 10 times as great as it now has without re-use of water. Re-use techniques, using the water after self-purification in streams or after special chemical purification, would let Illinois support a population many times greater yet.

Our surface water resources are adequate for any foreseeable needs of the state, but they can seriously deteriorate if we fail to husband them.

Soil-Water Relationships

The principal source of turbidity in most rivers is the erosion of soil from the land. This is clearly illustrated by considering the Illinois River Valley. It is calculated that the total amount of suspended material which would be discharged into Illinois River by populations which use it as a place of waste disposal would amount to approximately 75,000 tons per year if sewage were untreated. This would average about

FIG. 2.—Soil particles leaving the cultivated field.

FIG. 3.—Sediment deposit along a small stream in Illinois.

8 to 10 parts per million. Modern sewage treatment methods could reduce this by about 90 percent: the total suspended solids discharged into the river from treatment plants thus averages about one part per million.

In comparison, the amount of silt which reaches the river from eroding agricultural land is estimated at 6 million tons annually or 418 parts per million. The problem of clarifying the Illinois River is therefore to a large extent an agricultural problem, although it is also a pollutional problem. The soil particles which discolor the Illinois River originate on the cultivated farmland of the drainage basin, as illustrated in figure 2. The answer to the problem lies in the establishment of practices and farming methods that will reduce the loss of soil from farms. Establishing these practices is a slow job, but the County Soil Conservation Districts are at work on it.

Source of Soil Pollution in Illinois

Most people think of erosion as a phenomenon that occurs primarily on steep lands, frequently taking the form of gully erosion. State Water Survey studies indicate that the bulk of the sediment does not come from steep land. Most of the sediment reaching Illinois streams comes from sheet erosion of comparatively level or gently sloping lands, lands which are being used for production of intertilled crops (corn and soybeans). Difficulty arises due to the fact that the land is kept bare by continual tillage so that it is more readily erodible. The absence of a protective cover of vegetation intensifies the action of splash-erosion by raindrops. From the farms the silt finds its way through drainage ditches and small streams into the major tributaries and thence into the main river. Along each of the small streams and major tributaries, some of the sediment is deposited. Figure 3 shows a sediment deposit along the course of a small intermittent stream. A substantial proportion of the silt, however, still reaches the main river.

A century ago the Illinois River valley was an area largely devoted to prairie and timber. An analysis of the soil survey maps indicates

that of the total area of the Illinois valley in Illinois, 21 percent was originally timberland, 61 percent was prairie, and 18 percent was terrace and bottomland soils.

The Illinois program of sedimentation study is built around work by the State Water Survey in measuring the actual amount of sediment accumulated in reservoirs, and in compiling the hydrologic and engineering facts relative to each of the reservoirs. The lake owners provide records of construction, modifications and use, and labor to aid in the actual surveys. The Office of Research, Soil Conservation Service, contributes technical advice and guidance and furnishes some of the equipment for the work.

Cooperating in the studies, the Soil Conservation Districts within the counties, which are operated by local farmers, collect data on the erosion on the land. The data include complete or sample surveys of conditions on the watershed for each reservoir surveyed, such as location of eroding areas, extent and degree of erosion, slopes of land, and soil groups involved in the erosion process. The Agricultural Experiment Station of the University of Illinois analyzes samples of sediment taken during the engineering survey of the lake to determine the source of the sediment. The Experiment Station also summarizes the conservation survey data furnished by the local districts and directs the analysis of the survey so that the points of most serious erosion may be determined.

Figure 4 shows a sediment deposit in a public water supply reservoir on the Illinois River basin.

Under this cooperative program, the Water Survey has been involved

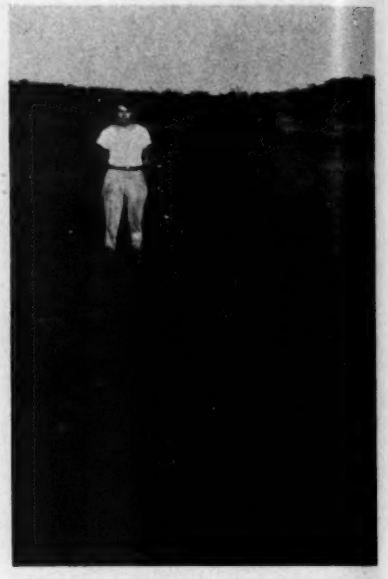

FIG. 4.—Deposit of silt in an Illinois reservoir.

in the surveying of 14 reservoirs, eight of which are located in the Illinois valley. (See fig. 5.) In choosing a site for survey work it is necessary to give consideration to kinds of soils involved in the watershed, as determined from basic data furnished by the State Soil Survey, and on many other factors, such as the rainfall, the topography of the land, and the farming practices in the area of study.

The results of the Illinois surveys are summarized in figure 6. The amount of silt that arrives in reservoirs is shown as the vertical axis, and the size of the contributing watershed is shown as the horizontal axis. From this graph it is seen that the contribution of silt into reservoirs from small watersheds is greater per square mile than the amount of silt that arrives in reservoirs which receive the flow from large

watersheds. This occurs because a portion of the sediment drops out of the flow of water enroute from the point of erosion to the reservoir. There is a substantial loss of sediment on small watercourses along the way (fig. 3).

Figure 6 does not indicate that erosion is worse in small watersheds than in large ones, but rather that less sediment per square mile arrives in the large reservoirs than in the small ones. The average annual rate of sediment production on the smallest watershed studies is in the neighborhood of 3 acre feet per square mile, which checks reasonably well with a mean figure of 7 tons of sediment per acre, estimated by studies on the land.

Silting Rate of Illinois River

An analysis of the data shown in figure 5 makes it possible to estimate what is happening in the Illinois Valley. Using existing reservoir survey data, the amount of sediment

Fig. 5.—Reservoir sedimentation surveys in Illinois, April 1, 1950.

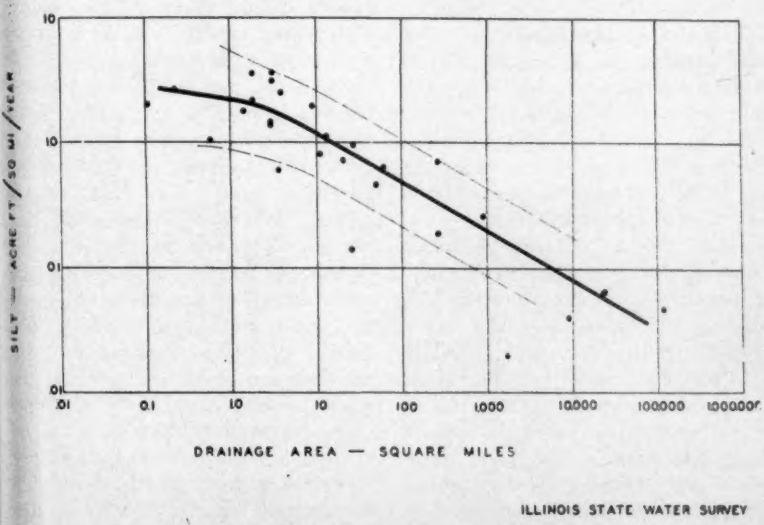

Fig. 6.—Sediment production rates in Illinois.

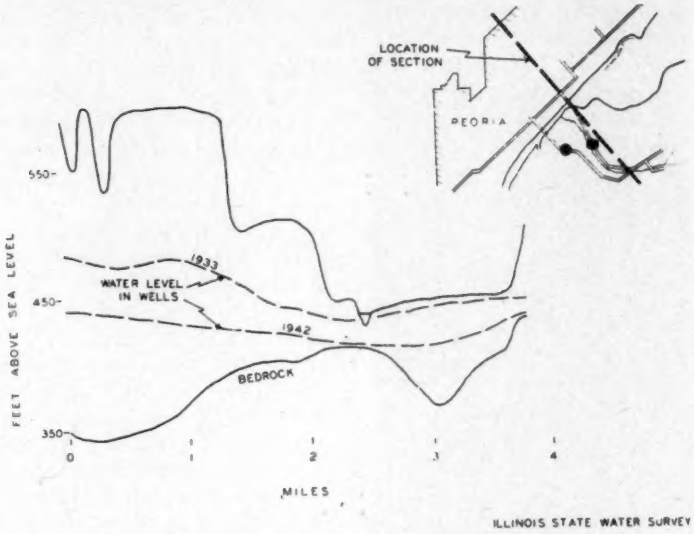

FIG. 7.—Groundwater cross-section at Peoria.

reaching the Illinois has been estimated, together with the amount of sediment that passes on out of the Illinois. We find that the total erosion in the Illinois valley is probably in the neighborhood of 68 thousand acre feet per year. The amount of this sediment which reaches the Illinois River is of the order of 4,000 acre feet per year. The amount which is discharged at the mouth of the Illinois is approximately 1,500 acre feet of sediment per year, leaving about 2,400 acre feet of sediment deposited along the Illinois valley. If we estimate the length of the Illinois as 295 miles, and the mean available flood plain of the valley as 4,640 feet wide, we find that enough sediment deposits to cause the valley floor to rise at the rate of about one foot in 70 years. The rate of sedimentation in the channel proper is probably considerably higher.

Figure 7 shows the situation which has developed at Peoria. The figure depicts a cross-section through the city of Peoria taken as shown in the heavy dashed line in the upper righthand portion. It is a cross-section at right angles to the river at the bottom of the Peoria lake, at the beginning of Peoria Narrows. In this cross-section it may be seen that groundwater levels in 1933 were generally higher than those in the river. The heavy industrial use which has grown in the last few decades at Peoria has resulted in a lowering of groundwater levels to the point where, in much of the Peoria region, groundwater levels are now far below the level of the water in the river. In most situations it is expected that the creation of such a situation will lead to discharge of water from the river into the ground. Water Survey studies indicate that this happens to a very

small extent at the locations shown, so that the groundwater deposits in the Peoria region must depend primarily on water entering them from other sources than the Illinois River (1). Thus the presence of sediments in the river exert a marked adverse effect on the availability of groundwater for industrial use.

Summary

There is an extraordinary relationship between soil and water resources which is not given adequate consideration. It is a complex relationship, but the basic facts are known and can be applied in the interest of conservation of surface water.

Over-development of groundwater resources is taking place at a few areas in Illinois. Eventually the cost of pumping the water from progressively greater depths may be a stronger controlling factor than any legal conservation measures. In the Chicago area this may mean a greater demand on Lake Michigan, where from the engineering point of view a considerably larger withdrawal could be made.

There are solutions for every water shortage occurring in Illinois. It is our responsibility to spotlight the facts on water resource availability and use. As the activities of men cause increasing interferences in the use of water resources, and regulation comes to be advocated, these facts will become the basis for deciding what is to be done.

REFERENCE

(1) "Groundwater in the Peoria Region," Illinois State Water Survey Division Bulletin 39, 1950.

SLOPE STUDIES OF NORTHERN ILLINOIS

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In recent years considerable interest has arisen in the quantitative expression of differences and similarities of terrain from region to region.[1] However, most of these studies have been primarily concerned with a technique or method of analysis and representation, and have generally been exemplified by a single area. The applicability of these methods to various types of terrain and a comparison of results obtained from different landform regions has been largely, though not entirely, neglected. Moreover, none of the papers has presented any appraisal of the results of such investigations in terms of the results or, more especially, of the results as evaluated in terms of the number of data required and the time involved in their analysis. This paper reports results from the utilization of only two techniques, neither of them new.

Relative Relief

The first method is one introduced by Guy-Harold Smith in a map of "The Relative Relief of Ohio."[2] The method of calculation is simple. From topographic maps of an area the difference between the highest and lowest point in each five-minute rectangle is ascertained. These values are then entered on the manuscript map and isolines are drawn connecting the center of all rectangles having the same values.

Two areas in the United States have been mapped using this method —the state of Ohio by Smith[3] and the Driftless Area of Minnesota, Wisconsin, Iowa, and Illinois by Smith and Trewartha.[4] The Driftless Area contains areas of low relief on its margins, and Smith and Trewartha, by shading heavily the critical relief range were able to show strikingly that the borders of the Driftless Area coincided remarkably well with a particular local relief range. Western and northwestern Ohio have very considerable areas of moderate or slight relief and these, of course, were represented on Smith's map of the state. However, in both of these areas sections of low relief made up only a small part of the total area.

The principal objective in applying the method to northern Illinois was to determine from a comparative study of the various relative relief maps produced and the topographic maps of northern Illinois what results could be obtained in the representation of smaller differences in local relief in an area of predominately low relief.

Figure 1 shows the local relief of northern Illinois using the method developed by Smith and using the same relief value limits. Five conclusions can be reached almost im-

[1] A large number of these studies are summarized and discussed in: Louis A. Wolfanger, *Landform Types*, Mich. Agric. Exp. Sta. Tech. Bull. 175, East Lansing, Mich.

[2] Guy-Harold Smith, "The Relative Relief of Ohio," *Geog. Rev.*, Vol. 25, 1935, pp. 272-284.

[3] *Ibid.*

[4] G. T. Trewartha and G.-H. Smith, "Surface Configuration of the Driftless Cuestaform Hill Land," *Annals Assoc. of Amer. Geographers*, Vol. 31, 1941, pp. 25-45.

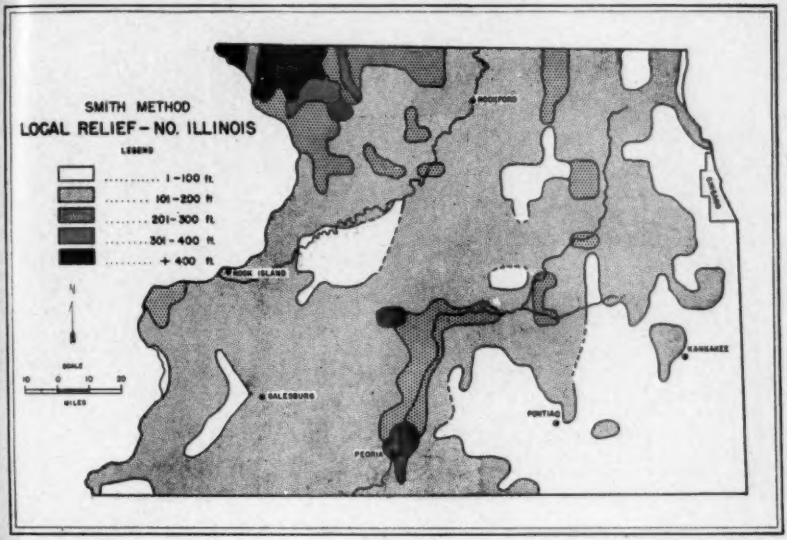

FIG. 1.

mediately from the most cursory inspection of the map: (1) the overwhelming preponderance of the land in northern Illinois has less than 200 feet of local relief; (2) the glacial lake plain of Chicago, much of the Kankakee River drainage way, and the Grand Prairie area have very low relief—less than 100 feet; (3) the only section of northern Illinois having strong relief is the Driftless Area in the extreme northwest corner of the state; (4) lands immediately adjacent to the Middle Illinois Valley have moderate local relief, and (5) the outwash plain south of the Rock River in the Prophetstown area and eastward is an area of low relief.

Very little else of value can be ascertained. The tongue of moderate relief (201-300 feet) extending southward from the northern border west of Rockford undoubtedly reflects the influence of the Marengo moraine but it is wider than the moraine and bears little relationship to its form. The compact area west of the Fox River occupies part of the morainic knot in central Kane County but it bears no significant relationship in either shape or size to the terrain situation in the area viewed either in the field or on topographic maps. The greatest relief in the southern part of the map occurs where the Bloomington moraine crosses the Illinois River valley. Other minor features have even less significance.

In calculating local relief from contour maps having a 20-foot contour interval it is obvious that there will be more rectangles having values that are multiples of 20 than are multiples of 10 only. In the construction of any isopleth map it is better to use value limits that have a low frequency than limits having a high frequency of occurrence. Another map was constructed using 90 feet and 190 feet as the value limits

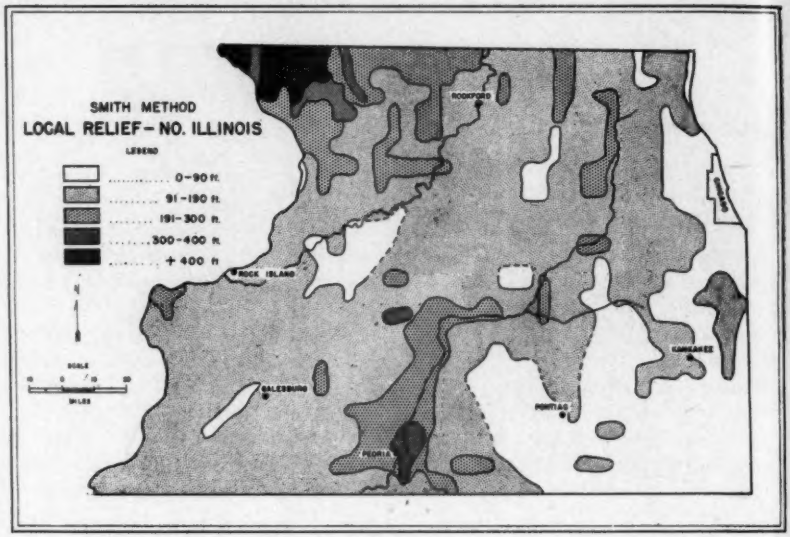

FIG. 2.

instead of 100 and 200 feet (fig.2). All the major generalizations apparent on the first map are equally apparent on figure 2, but the borders of the major areas and the shapes and sizes of many of the minor areas are quite different. Some of the new outlines of these minor areas seem to be more meaningful in terms of portraying actual terrain conditions; about an equal number appear less so.

Once the local relief values have been entered on the base map any number of relative relief maps can be constructed on overlays using any relief value limits that are desired. Several other local relief maps using various relief value limits were constructed. Several of them had much lower value ranges. On all the maps the main outlines of local relief conditions in northern Illinois were clear; on none of them, in the author's opinion, were minor features any more satisfactorily portrayed than on the maps illustrated.

Smith and Trewartha have suggested that experimentation be made to discover a particular size rectangle that will portray conditions more satisfactorily in any particular region than would either a larger or smaller rectangle. The author carried on no experiments of this kind, because of his conviction that whatever was gained in the portrayal of local areas by varying the size of the rectangle would be more than offset by the greatly added difficulties to inter-regional c o m p a r i s o n that would certainly result from using a variety of different sized rectangles from region to region.

AVERAGE SLOPE CONDITIONS

An isarithmic map of average slope can be constructed for an area in a manner similar to that of a map for relative relief except that values

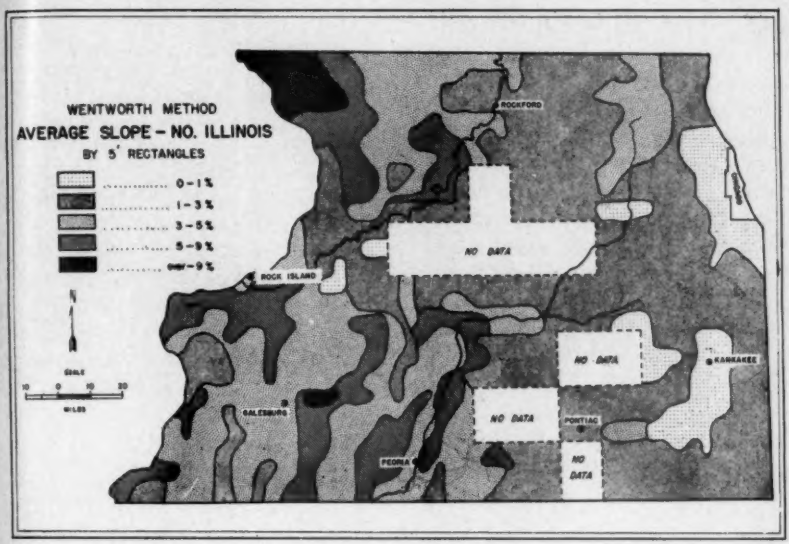

FIG. 3.

for average slope of a 5-minute rectangle as calculated by a method promulgated by Wentworth[5] are used instead of local relief. It must be kept clearly in mind, however, that the two concepts are not the same. It is possible for an area to have strong local relief and comparatively low-angle slopes, or conversely for an area to have low local relief and high-angle slopes.

Figure 3 shows a map of northern Illinois constructed by this method. No sharp general conclusions are immediately apparent. The Chicago lake plain shows up as an area of very low slopes as does a small section around and south of Kankakee. The extreme northwestern area is the only large division having steep slopes. In a very general way it may be noted that the areas flanking the three major rivers of northern Illinois—the Rock, Mississippi, and Illinois—have somewhat steeper slopes than the areas farther removed from these valleys. But with the exceptions just noted, the pattern appears to bear no significant, visible relationship to actual slope conditions in the area portrayed.

In the average slope maps, however, a somewhat better map may be produced by using other slope value limits. In figure 4 the Chicago lake plain is much more satisfactorily delimited and the southeastern corner of the map stands as a clear-cut single area having universally low-angle slopes. Moreover, the morainic belt circling the south end of Lake Michigan stands out quite clearly from the flanking areas of smoother terrain. There is a much stronger suggestion of the smooth outwash plain south of the lower Rock River. Elsewhere on the map the representation seems no better or no worse than that in figure 3.

[5] C. K. Wentworth, "A Simplified Method of Determining the Average Slope of Land Surfaces," *Amer. Jour. of Science*, Series 5, Vol. 20, 1930, pp. 184-194.

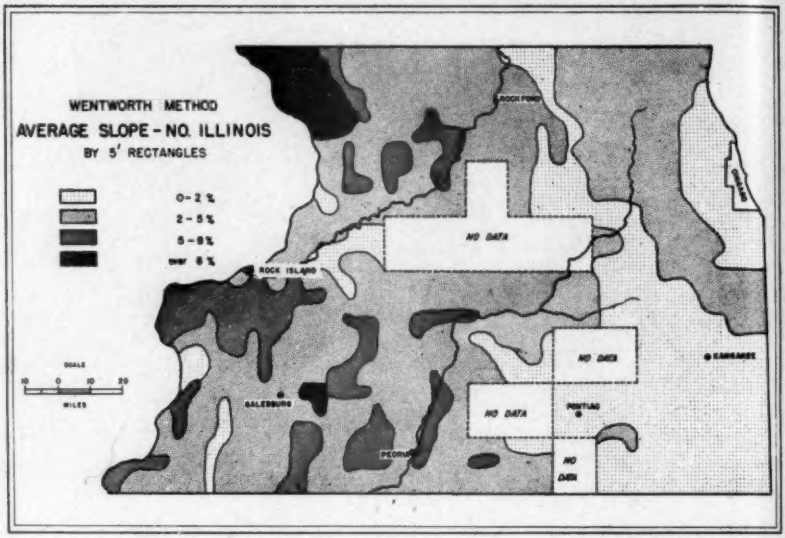

FIG. 4.

EVALUATION OF RESULTS

The local relief method of expressing quantitative differences in terrain appears to be a useful and practical method when applied to areas of considerable size. Regardless of the relief value intervals used, major differences in local relief stand out clearly. Smaller details of the resultant patterns are ordinarily almost meaningless. The method appears best adapted to small scale maps.[6] The method has two further advantages from the standpoint of practicability. First, the work can be done rapidly. This is especially true if the relief value limits are determined in advance. A rapid inspection of each rectangle will indicate whether or not the maximum relief figure will fall near a value limit. If it does not, then it is unnecessary to determine precisely the absolute extreme values. It should be kept in mind, however, that if the relief of each rectangle is expressed only in terms of a value range it will be impossible to make more than one map from that set of data. Secondly, less reliable data will give satisfactory results. This is especially important in areas where the topographic maps are old, on small scales, and have large contour intervals.

The method of average slope depiction appears much less useful. Calculations using this method are much more time consuming. Even with practice it is not possible to count an average of more than two sheets per hour. Moreover, if the work is done steadily for more than an hour it becomes a great strain on one's vision.

If the results were highly satisfactory they might well be worth the laborious procedure necessary to obtain them. But in an area such as

[6] In many cases small local details, resulting largely from statistical accident, might best be omitted.

northern Illinois this does not appear to be true. The concept of average slope is meaningful only insofar as the majority of the slopes in an area have some approximation to the average slope. In very large sections of northern Illinois, flat interstream areas are interspersed with steep slopes along the narrow valley sides. The resultant average slope figure is nothing more than a meaningless statistical average which merely conceals the facts of actual slope conditions in such an area.

Finally, reliable topographic maps are necessary for calculations of average slope. Since reliable and detailed data are necessary for the construction of such maps, it appears to the author that if such data are available some better method of expressing slope conditions in an area can be devised. Experiments on the problem are proceeding at present.

GEOLOGY

STUDENT PROJECTS AND THEIR PLACE IN GEOLOGIC EDUCATION

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The suggestion has been offered that it would be appropriate at this meeting to make some remarks concerning the work in geology at Augustana College. Back of this suggestion was the thought that most geologists present are university men, who may not have much familiarity with what goes on in the little world which is the one-man or two-man geology department of a liberal arts college. Also, a glimpse into the activities of one such department might be of some interest to the geology teachers from sister colleges.

I must forego any historical introduction, other than to note that at this college geology has been taught for almost three-quarters of a century. The pioneer teachers, Josua J. H. Lindahl and his student and successor, Johan A. Udden, were exceptional men who placed scientific instruction on a basis that was both sound and broad — broad enough to include geology almost from the beginning.

Twenty years ago a full major in geology was introduced in the curriculum, so that this science was placed on the same basis as the related disciplines of chemistry, physics, biology, and mathematics. Augustana was the first Lutheran college in the country to take this step —several have since followed its example—and it did so because the men who were then the academic leaders of the institution believed that the cultural value of geology justified such increased emphasis.

Full departmental status involved new, advanced courses, which in turn necessitated additional equipment and supplies. A modest initial budget sufficed for purchase of study collections, maps, and a few essential instruments, but much else seemed necessary for a well-equipped department. With reference to such needs, the Physics Department seemed to have a good working solution: what one can't buy, *build*. There remained the problem, to be sure, of how an instructor was to do this with a schedule which regularly included four or five different courses.

In the new department, a solution early presented itself with the assignment of an undergraduate student assistant to the department. This assistant, R. W. Edmund, had the traditional farmer boy's resourcefulness and capacity for work, and given free reign to go ahead on his own had presently equipped the department with useful wall charts, structural models, relief maps, models illustrating construction of topographic maps, and other teaching materials which are still giving good service—not to forget his *opus magnus,* a working geyser model which could be operated before the class, and which no student could ever forget because it erupted with such startling abruptness, the first

spurt of water always hitting the ceiling.

When Edmund graduated—happily to return fifteen years later—the principle of student collaboration in our work had become pretty firmly established. I say "our" because I am speaking also for the several geology teachers who at various times have been on the staff: Leland Horberg, Chester Johnson, Troy Péwé, Barbara Hender Morris, and Rudolph Edmund. However, this principle—if it may be dignified with so formal a term—was long in operation before it was recognized and its possibilities consciously developed. For only gradually was it realized that in almost every geology class there are students who become so interested in the problems of their course that they will welcome an opportunity to do volunteer outside work in it. By encouraging such spontaneous interest wherever it appeared, and by directing it into specific, constructive channels, eventually a situation developed in which much of the work in the department was in the hands of the students, and this has continued to be the case.

How this has worked out may be made clear by some illustrations. Eugene Wittlake, intrigued by the dramatic sweep of Cenozoic mammalian development, undertook preparation of a display depicting the evolution of the horse. This display proved so useful that Lorenz Peterson undertook a parallel project for a representative invertebrate group: the evolution of the Cephalopods. Keith Hussey, becoming involved in the Daemonelix problem, drove out to western Nebraska, studied these curious fossils in the field, and collected a good specimen which he hauled back to the college, there preparing the museum mount which still stands as a record of his undergraduate enthusiasm. Vernon Swanson constructed a geological column showing the formations penetrated by a deep well two blocks west of the campus; this column, mounted just inside the door of the museum, has been useful in many ways. Barbara Hender Morris classified the Mazon Creek collection built up during many years of annual field trips to that locality. Students with a flare for writing, like Jean Soady, have issued Departmental News Letters. Others, especially interested in museum work, like Donna Builte, have aided with making labels, numbering and cataloging, and arranging displays. Still others have assumed responsibility for programs of geological films, presented to the general student body. Wendell Swanson has just constructed some display cases which we badly needed but could not purchase. This year Richard Edmund, Donald Danz, and John Rakus have been engaged in constructing a stream table, now well on the way to completion. Dick Fetzner and Kenneth Larson have been busy with a geyser model to replace the now legendary one built by Edmund years ago. Recent purchase of a rock saw and polishing equipment have opened up a variety of new possibilities.

Not all these projects can be displayed, but we hope that some of our visitors, despite their crowded schedule, may find it possible to visit the Geology Museum in Wallberg Hall, which houses many exhibits, most of them relating to vertebrate paleontology. There you will see two large ichthyosaurs, salvaged as fragments from an eastern warehouse which burned to the ground, which were reassembled by Charles G. Johnson till almost as good as

new. Joseph Hoare found preparing fossils even more absorbing than varsity sports or the college choir, and his brother Richard now continues his long-range project of mounting dinosaur bones. Ansel Gooding, an amateur archeologist, turned his hand to repairing fossils instead of pottery, and completed a number of jobs of high professional quality, including the fine *Pteranodon* skeleton on the north wall of the museum. Three years of tedious but intriguing work by five different students were required to complete the mounting of the mosasaur skeleton which Mr. C. B. Campbell made available to the Museum.

Projects like these have been undertaken in various ways: some purely as an expression of interest, and for the satisfaction of doing them; several as official, recurrent projects of the Geology Club; others, which involved actual research or much delving in the technical literature, as seminars, for which students have received one or two senior college credits; and still others as projects undertaken by student assistants, who receive nominal recompense for at least part of their time.

It seems to us that student participation in extracurricular activities such as these has been all for the good. The impulse, whatever its nature, which launches a student on a project almost always develops into deep interest, and I suspect that long after he has forgotten many a classroom discussion he retains a vivid recollection of what he learned through his individual work. Some students have discovered or developed special skills which later have proved useful in graduate school, or in their own professional work. And quite understandably, students derive lasting satisfaction from having made a significant, worthwhile contribution of some kind to the work of the department.

It is to be expected that through deepened interest, developed in this way, some students might be led to choose geology as a major or even as a career. To some extent this has probably been true, but in encouraging student projects our purpose has always been to help the student grow into a fuller appreciation of the subject matter of geology. We have had, if anything, a special interest in the student who, while preparing himself for music, economics, or some other non-scientific field, has become sufficiently interested in geology to undertake volunteer work in it. The biology major who prepared our fossil horse material undoubtedly became a better biologist for his venture into paleontology; and the pre-seminary student who, through several years, made a hobby of working up vertebrate fossils, is probably a better clergyman for this enlightening, if somewhat unorthodox, experience.

To the institution, the advantages of student projects are quite self-evident. A brief tour of the department will suggest how it has been enriched by illustrative material most of which could not otherwise have been provided, even if funds had been available.

Also, through student assistance the instructors have been relieved of many time-consuming duties, and so freed to devote their best energies to actual instruction. Thus it has become possible for them to teach almost all laboratory sections themselves, rather than to delegate them to assistants.

Most important, perhaps, has been development of, or at least approach

to, a situation in which teachers and class members become closely associated as fellow students, engaged in a common pursuit. This relationship is as desirable in the undergraduate work which is the province of the liberal arts college as it is in the higher levels of the graduate school. And among intangible values such as these one would certainly include the vital personal interest and loyalty which students develop when they are allowed to become collaborators in the work of the department—attitudes which are not likely to end with graduation.

It is worth remarking that the Geology Museum, which thus has been developed mainly by the students, has extended its influence beyond the campus. Not only are there daily individual visitors, here from off-campus, but the Museum is now in regular use by the science classes and clubs of the public schools of Rock Island and nearby cities, and also by many other organizations such as boy scout and girl scout troops, Y. M. C. A. classes, amateur science clubs, and church organizations. So far as possible, instructors or advanced students meet these groups, speak to them, and answer questions; and in many cases when groups in the community request talks on geology they are invited to come to the Museum, where they can be shown the actual documents which the geologic story interprets.

The many small boys who come to the Museum with their puzzling concretions, a l l e g e d meteorites, and precious agates, or to solicit information on dinosaurs and saber-toothed tigers, are also very welcome, even though they leave grimy finger marks and nose prints all over the cabinets.

The appreciation of these public school children and their harassed teachers, who often must teach geology units in general science courses when they have no background whatever in the subject, is so real as often to be touching. I confess that we also find it rather sobering, for we have the growing conviction that helping these groups—the forgotten people, so far as geologic science is concerned—is one of the really important things that we can do. One would like to believe that, some day, geologists will see to it that every community is provided with a geology museum, however small, stocked, perhaps, from the superabundance of the great museums in our large cities. Geology will not be the loser for such generosity to the children of today, who will become the taxpayers of tomorrow. In saying this I am not unmindful of the splendid work which the Illinois Geological Survey is doing along these very lines; rather, I would here acknowledge it.

And so, at this college, while the main obligation continues to be the teaching of general geology to increasingly large numbers of general college students, we find ourselves reaching constantly toward two other somewhat diverging objectives: the preparation of a relatively small group of students for graduate study, on the one hand; and cooperation with the community, especially the public schools, on the other.

I realize that these remarks may not be wholly appropriate to this group, for admittedly they relate to the methods and purposes of geologic instruction rather than to the subject matter of our science. Also, they really present nothing new, for our experiences at Augustana have undoubtedly had their counterpart at many other like colleges. I sup-

pose that most other geology teachers have discovered, as we did, that they have been able to achieve their purposes only by taking their students into partnership with them, and that in trying to remedy the shortcomings of their small departments they have unwittingly transmuted weaknesses into elements of strength.

It is axiomatic to say that students will become interested in a field to the extent that they give themselves to it, and that instruction succeeds in the measure that it becomes a cooperative venture. Yet these principles, old as education itself and applicable to all ages and levels of instruction, are so important that it may not be too much out of order to re-emphasize them through one more repetition. And as geologists, we should realize that few subjects lend themselves to application of this basic philosophy of education as well as ours does.

SOME EASILY CONSTRUCTED MODELS FOR TEACHING OPTICAL MINERALOGY

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The study of optical mineralogy generally offers considerable difficulty to the average student of geology. Any method, therefore, which will enable the instructor to simplify the subject matter and enable the student to grasp the concepts involving three dimensions may be considered worthwhile.

A definite contribution to the simplification of teaching as well as learning the fundamentals of optical crystallography has been made by those who have suggested or described the numerous kinds of models which illustrate the various optical and crystallographic phenomena. At one extreme are those models so elaborate in their nature as to require great skill in construction. At the other extreme are models so simple in their makeup that they may be readily prepared by almost anyone. This paper deals with models of the latter group; and although these models are relatively simple in their construction, they have, nonetheless, proved very successful in teaching mineral optics, and have greatly aided those students who have experimented with them.

Most of the models described in the literature for representing the various relationships between optical and crystallographic properties consist of transparent glass, celluloid or plastic-like crystal forms within which the crystallographic axes and principal optical directions are represented by ruled lines, wires, or threads. Most of these are permanent and can be constructed with considerable accuracy. Any one model is somewhat restricted in its use; a different model must be prepared to represent each set of relationships. Such models do not, therefore, permit the flexibility required for demonstration and for student use as do the simple types described in this paper.

It is not intended here to consider models other than for biaxial crystals. If models for other optical types are desired, they can be prepared with little difficulty. It is hoped that the few examples given below will suggest to the reader ideas for making new models and simplifying or improving older ones.

Demonstration Models for Biaxial Crystals

Satisfactory models may be made of soft pine by cutting blocks of desired lengths from good quality 2 x 4 inch material. These blocks can be shaped into solid models with the crystal faces desired. For simplicity, models with only the three pinacoidal forms are illustrated here, but it will be found desirable to prepare some models with a prism form and perhaps with domes and bipyramids.

Orthorhombic models.—An orthorhombic model about 1¾ x 2⅝ x 4 inches is quite satisfactory, and when finished appears as in figure 1. The two rows of dots on each face represent small holes drilled directly toward the center of the model to

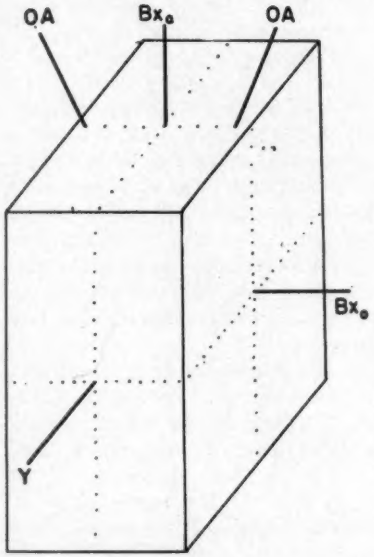

FIG. 1.

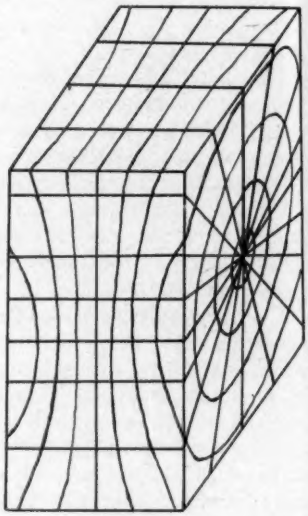

FIG. 2

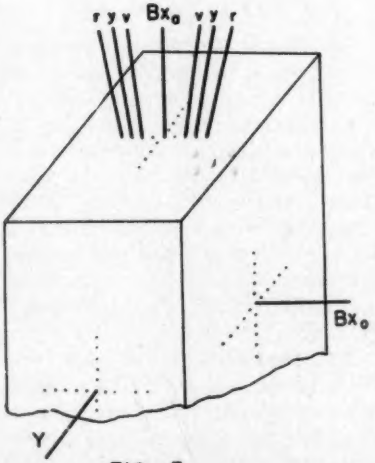

FIG. 3.

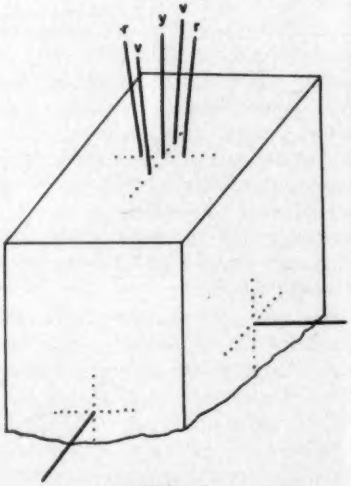

FIG. 4

a depth of about one-half inch. The points of intersection of the rows of holes lie at the centers of the pinacoids and the rows are parallel to the crystal axes. If round wooden sticks, about two inches long, are now inserted in the six holes at the intersections of the rows, the three principal optic directions X, Y, and Z may be represented in their proper positions parallel to the crystallographic axes. By inserting four more wooden sticks in the proper holes, the positions of the optic axes may be shown for a number of different optic angles. It is suggested that a relatively small number of holes be made to represent different optic angles. Holes spaced about 10° apart will be quite satisfactory.

To determine the spacing of holes, the following equation may be used:

$$D = \frac{\tan VT}{2}$$

where D is the distance from the center of the crystal face to the hole position desired, V is half the optic angle desired, and T is the thickness of the model measured perpendicular to the face to be drilled.

This model is suitable to demonstrate the unusual but instructive optical phenomenon of the lithiophyllite-triphylite series. In the most iron-poor variety the optic plane is parallel to (001) and the 2V about the b-axis is 65°. With an increase in iron, the optic angle decreases to zero and the mineral becomes uniaxial. As the iron content continues to increase, the optic plane becomes parallel to (100) and the optic angle about the b-axis increases to 90° and then begins to decrease about the c-axis until it again becomes zero and the mineral is uniaxial. With additional iron, the optic plane is believed to shift to a position parallel to (010) and the optic angle increases again about the c-axis.

Monoclinic models.—The monoclinic model as shown in figure 2 may be prepared with slightly greater difficulty. After preparing the desired crystal model, the center of the (010) face is located and radial lines drawn therefrom to the edges of the crystal face. These lines are continued across the faces in the zone of the b-axis parallel to the zone line. The radial lines might be spaced 10° or more apart. Next, concentric circles are drawn on (010), and their spacing is determined by the following equation:

$$r = \frac{\tan VT}{2}$$

where r is the radius of a given circle, V is half the optic angle desired and T is the thickness of the model measured perpendicular to (010). On the faces in the zone of the b-axis, hyperbolic curves are drawn. These can be roughly determined by computing their spacing along three of the parallel lines on each face and drawing smooth curves through these points. The spacings may be determined by use of the following formula:

$$S = \tan VM$$

where S is the distance measured right or left from the plane of symmetry, V is half the optic angle desired, and M is the distance from the parallel line to the b-axis measured on (010).

Where straight lines intersect curved lines, holes are drilled toward the center of the model to a depth of about half an inch. This model may be employed in much the same manner as the orthorhombic model. Extra sets of round sticks may be

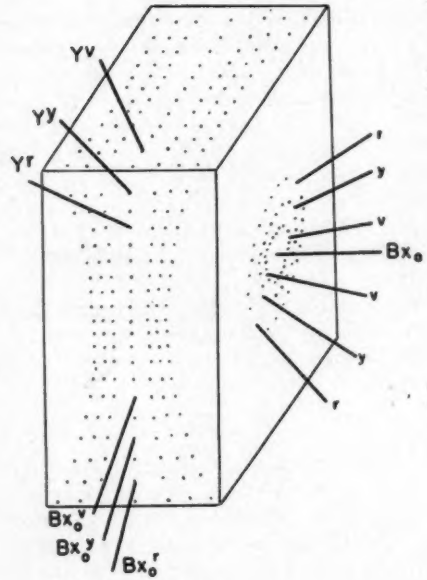

FIG. 5

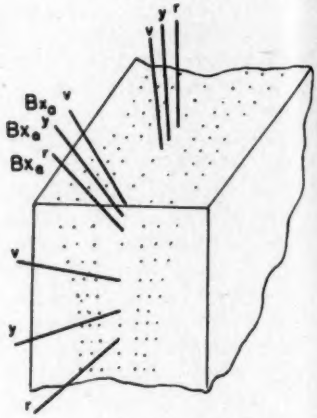

FIG. 6.

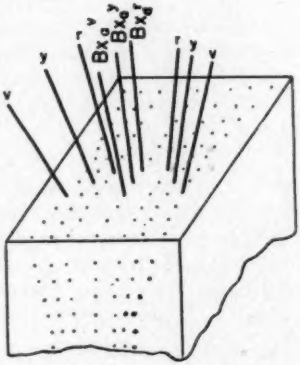

FIG. 7.

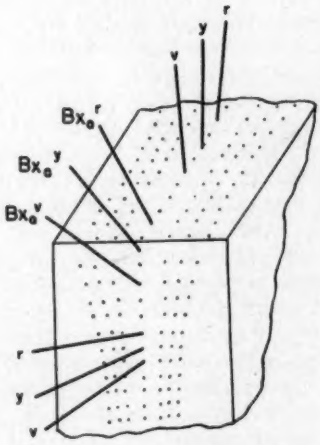

FIG. 8

used to show the positions of crystallographic a and c.

Triclinic models.—Triclinic models may be prepared by following essentially the same rules and with only slightly greater difficulty. It is suggested that only a few possible orientations be selected. Each set of holes for the directions X, Y, and Z must, in general, have an accompanying set of holes for optic axis positions.

Dispersion models.—A model like figure 1 or one like figure 3, in which a fewer number of closely spaced holes have been drilled, serves to illustrate the types of dispersion in orthorhombic crystals. Three sets of wooden sticks are used to represent the optic axes for different colors of light. One set is painted red, one yellow, and one violet. Figure 3 shows the model arrangement for dispersion of 2V with $r > v$. An arrangement like figure 4 illustrates crossed axial plane dispersion where the optic plane for red light is parallel to (100) and that for violet light is parallel to (010). The yellow stick in the position of the acute bisectrix indicates a uniaxial character for yellow light.

Figure 5 illustrates the monoclinic model for representing dispersion of 2V combined with dispersion of orientation. The principles of construction of this model are the same as those for figure 2. It is recommended, however, that there be a greater number of holes in each row and that the number of rows be reduced to seven. Figure 5 illustrates a condition in which $Bx_a = b$, crossed dispersion, and $r > v$. Figure 6 shows $Y = b$, inclined dispersion, and $r > v$. Figure 7 shows $Bx_o = b$, horizontal dispersion, and $r < v$. Figure 8 illustrates the type of relationship which exists in some minerals like epidote. If one optic axis only is observed in the interference figure, the dispersion appears $r > v$. If the other axis is observed, however, the dispersion appears reversed. Actually the dispersion of 2V is $r > v$. In figures 6 and 8 an extra hole is shown for the acute bisectrix for yellow light (Bx_a^y).

A model may also be constructed to illustrate several general examples of dispersion in triclinic crystals.

Permanent Reference Models

A very helpful set of models may be prepared for student study or reference work by employing the well-known Krantz pearwood models. After selecting the desired models, small holes are carefully drilled and long wire brads inserted to simulate the optic axes and the principal optic directions in each mineral represented. If desired, extra holes may be drilled and extra brads inserted to represent crystallographic axes as well. If the brads representing crystal axes are painted one color, those representing optic axes another color, and those representing the principal index directions a third color, each set will stand out more clearly. To produce a more finished model, the heads of the wire brads may be clipped and the rough ends filed smooth before painting.

Problem Models

Instructive problems and exercises may be undertaken by the student with the aid of inexpensive and easily acquired materials. Each student is provided with three small blocks, an inch or so long, cut from pieces of balsa wood, and roughly formed to represent the three pina-

coids of the orthorhombic, monoclinic, and triclinic systems. Substitutes for balsa wood might include any soft material like cork or art gum. In addition the student should have a supply of straight pins with different colored heads. Different colors may be designated to represent the optic axes, crystal axes, and principal index directions. By inserting the round-headed pins into the balsa wood block an unlimited variety of problems may be worked out.

In order to reproduce a given optic angle, for example, the center of the model is held directly over the index mark of a small protractor placed on the table. By sighting down upon the protractor the pins are inserted to give the proper angle. The student should be instructed to insert all pins in such a fashion that if extended inward the pins would all intersect the model's center. Inserting pins at the proper angle may be facilitated by use of a simple type of protractor. From a point at the center of the long edge of a 3 x 5 inch filing card, draw a series of radial lines spaced at intervals of 5°. If each pin is aligned with the proper radial line of this protractor before it is inserted into the balsa wood, it will point directly to the center of the model and angles will be more correctly duplicated.

Just a few types of problems and exercises are suggested here. A list of optical data for a theoretical mineral might be given the student who is required to build up a model to illustrate as many of these data as possible. Again, the instructor might prepare a model and request the student to tabulate the optical data illustrated by this model. Starting with a given model, the student might be required to predict the type of interference figure which would be obtained for a specified orientation.

Even crude models prepared of common pins and pieces of pencil eraser may be employed to good advantage by the student in his microscopic work. A simple model of a biaxial crystal with the principal index directions and the optic axes may be used to help visualize the orientation of various grains under the microscope. It will enable the student to correlate the interference figure on a particular grain with the optical orientation of that grain. Simple models of this type will permit him to visualize more intelligently the relationship between extinction angle and grain orientation.

ATOMIC MODELS OF THE SILICATES AS AN ESSENTIAL AID IN THE TEACHING OF ELEMENTARY MINERALOGY

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Most present-day courses in elementary mineralogy are actually impediments to the progress of mineralogy and geology, and are not even introductions to a *science*. The most serious defect is the lack of logical development and presentation of fundamental unifying principles. A dogmatic approach results in the emphasis falling almost entirely upon the memorization of a vast amount of miscellaneous and apparently unrelated information concerning minerals—much of it erroneous. Heretofore, such a state of affairs may have been somewhat excusable because of insufficient fundamental information. Today, however, there is sufficient information about the behaviour and arrangement of atoms in crystals so that an attempt can be made to present some of the controlling principles necessary for an understanding of miner-

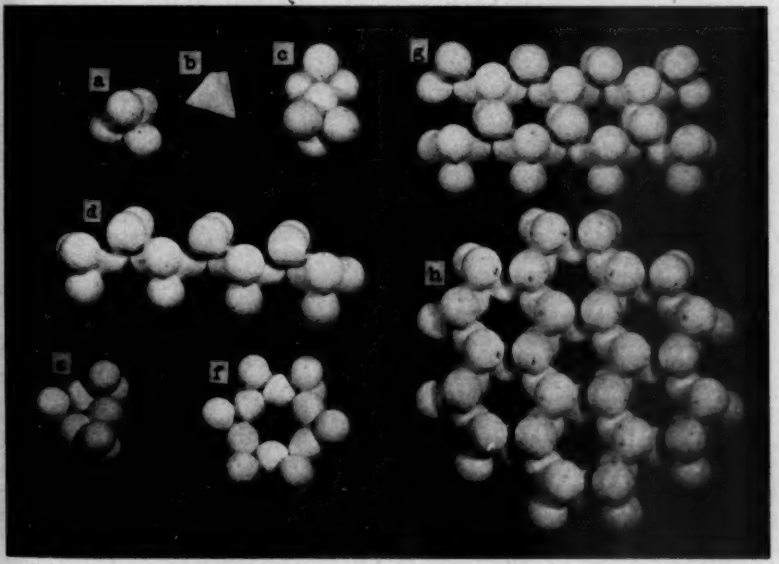

FIG. 1.—Common arrangements of silicate tetrahedra: a = independent tetrahedron characteristic of olivine; b = geometric tetrahedron for comparison with a; c = double tetrahedra characteristic of the melilite group; d = tetrahedral chain characteristic of pyroxene; e = three-membered tetrahedral ring characteristic of wollastonite and rhodonite; f = six-membered tetrahedral ring; g = double tetrahedral chain characteristic of amphibole; h = tetrahedral sheet characteristic of the micas. Tetrahedral three-dimensional framework characteristic of the silica minerals and feldspars not shown.

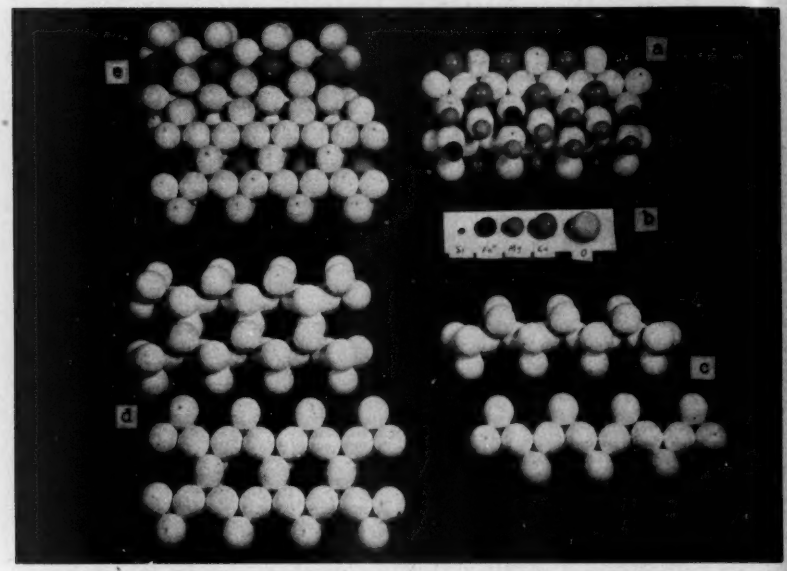

FIG. 2.—Method of assembling models: a = pyroxene showing arrangement of calcium and magnesium-iron atoms in parallel double rows (note isomorphism of magnesium and iron); b = index of atoms in pyroxene model *a*; c = method of assembling tetrahedral chains in model *a*; d = method of assembling tetrahedral double chains in model *e*; e = partly assembled model of amphibole, hydroxyl ions (gray) occupy large holes in double chains, arrangement of cations (not shown) like that in pyroxene model *a*.

als even on an elementary level.

The purpose of this paper is not to present a complete elementary treatment of such principles but simply to call attention to them and to show how readily they may be illustrated by atomic packing models of minerals. The value of this approach is particularly well demonstrated by the insight which it gives into the relations of the extremely complicated silicate group of minerals. However, before describing the atomic packing models, several highly simplified principles will be given first so that the significance and use of the models can be fully appreciated:

(1) The constituent elements occur as spherically shaped ions.
(2) Each kind of ion (Fe^{2+}, O^{2-}, Fe^{3+}, etc.) has a characteristic size (in general anions are larger than cations).
(3) Anions are attracted so as to touch neighboring cations and vice versa.
(4) The number of anions that can surround a cation (and vice versa) is controlled by the relative sizes of the respective ions.
(5) Different kinds of ions that have similar sizes (e.g. Fe^{2+} and Mg^{2+}) can equally well occur in the same kind of position in a crystal structure (isomorphism).

The most important conclusions to be derived from these principles are that most minerals, including silicates, can be considered as composed

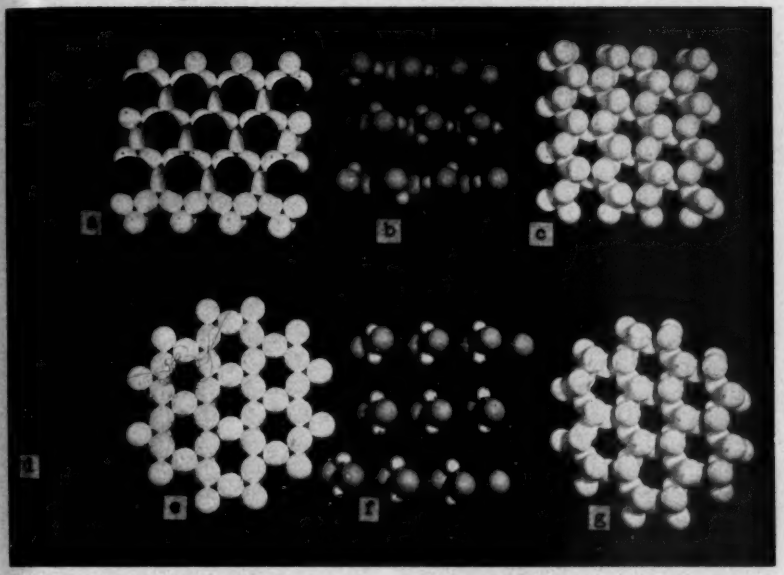

FIG. 3.—Method of making models with interchangeable parts that can be easily assembled and disassembled: a = silicate sheet with large potassium atoms (dark) resting in holes in sheet. b = strings of hydroxyl ions (large gray spheres) and magnesium-iron atoms which form a layer between silicate sheets *a* and *c*. Threefold arrangement of magnesium and/or iron atoms is characteristic of biotite and talc. c = silicate sheet. d = potassium atoms. e = silicate sheet identical to rectangular sheet *a* but with tetrahedra at corners removed in order to show hexagonal symmetry of sheet. f = strings of hydroxyl ions and aluminum atoms (small white spheres) which form a layer between silicate sheets *e* and *g*. Twofold arrangement of aluminum atoms is characteristic of muscovite, pyrophyllite and kaolin. g = silicate sheet identical to *c* but with corner tetrahedra removed in order to show hexagonal symmetry of sheet.

of ion spheres of different sizes, and that many of the properties of minerals depend upon the relatively simple geometric ways in which these spheres can be packed repetitively. An elementary account of these principles can be found in Stillwell (1938). Data on the sizes of ions can be found in Evans (1948).

It should be possible, therefore, to show the application of these principles by means of models of minerals constructed with spheres of different sizes representing the different atoms. Spheres of cork probably are the easiest to use. The Armstrong Cork Company makes cork spheres in any size from 3/8 to 3 inches in diameter. Entirely satisfactory models can be made with relatively few sizes. The following sizes have been found to be suitable:

1¼″ = oxygen, hydroxyl, fluorine, and potassium (1¾″ has been found to be more satisfactory for potassium in the micas)

1″ = calcium, sodium

¾″ = magnesium, iron, aluminum (½″ would be more accurate for aluminum)

9/32″ = shot or ball bearings for silicon

The use of different colors for the different kinds of atoms adds to the effectiveness of the models. The spheres can easily be joined together by means of heavy pins or brads from which the heads have been cut off. Models of particular minerals can be constructed from the data in Bragg (1937).

The fundamental unit of construction of the silicates is the so-called silicate tetrahedron which consists of a silicon atom surrounded by four oxygen atoms. This unit well illustrates the control on arrangement of atoms by their relative sizes because the sizes of silicon and oxygen are such that four oxygen atoms can just fit around each silicon atom (figure 1). One of the most important causes of the complexity of the silicate minerals arises from the variety of ways in which the silicate tetrahedra can be arranged (figure 1). In fact, the simplest and probably the most instructive method of making a model of a particular silicate mineral is to assemble several of the tetrahedral groups that compose the major part of that mineral, such as independent tetrahedra for olivine, single chains for pyroxene, or sheets for mica. In general, it will be found that these groups pack together rather snugly and that the other atoms in the crystal fit in the interstices. Large atoms fit in the large interstices and small atoms in the small interstices. Examples are shown by figures 2, 3, and 4.

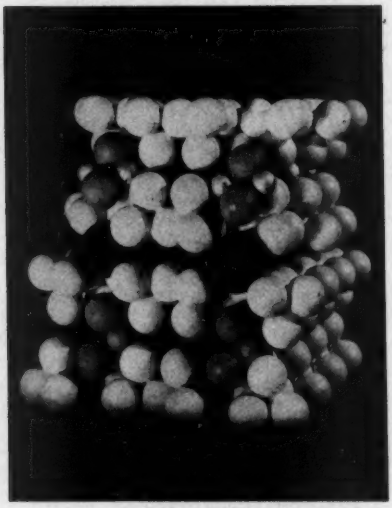

FIG. 4.—Composite model of mica made by assembling units shown in figure 3. Lower half represents biotite assembled from units *a*, *b*, and *c* in figure 3. Upper half represents muscovite assembled from units *d*, *e*, *f*, and *g* in figure 3.

The models are particularly instructive if the groups can easily be disassembled and reassembled by students. Figure 3 shows an example in which the groups are interchangeable and can be assembled in various combinations to illustrate almost all the sheet minerals.

Models such as those that have been briefly described illustrate vividly and fundamentally many of the varied properties of the silicates, such as isomorphism, derivation of the chemical formulae, cleavage, hardness, many of the optical properties; why certain alteration products may be favored; and why melts of certain silicates are viscous whereas others are fluid.

Grateful acknowledgment is made to Dr. Ralph E. Grim of the Department of Geology and the Illinois State Geological Survey, who has long recognized the value of atomic models in his researches on the clay minerals and who called to my attention the convenience of cork spheres. Mr. Merle Williams, a student in the Department of Geology, assembled the excellent models shown in the illustrations.

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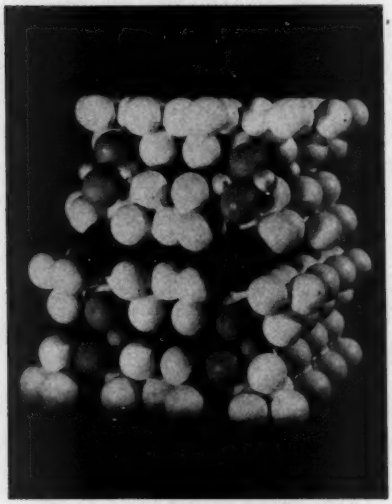

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GLACIAL LAKE MERRIMAC

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Named for a town at the crossing of Wisconsin River by the Elroy division of the Chicago and Northwestern Railway, Lake Merrimac came into existence in this part of the Wisconsin valley when the Green Bay lobe began to retreat from its terminal (Johnstown) moraine. The moraine and its outwash, blocking the valley, served as an effective dam, and the lake lengthened northeastward as the retreat continued. Its level appears to have stood at 850 to 860 A.T. during this time.

Overlooking the lake on the north was the southern of the two Baraboo Ranges which, 18 miles northeast of the drift dam, terminates abruptly where joined by the converging North Range. Here the upland surface drops off from 1200 to altitudes below that of the lake. Had there been no drainage into Lake Merrimac other than that of the adjacent retreating glacial front, and had no lowering from outlet erosion occurred, the lake would have continued to lengthen and expand as the glacier retreated north and east of this end of the Ranges and would have flooded the low country about Portage and north down the Fox River valley. Indeed, the upper Wisconsin River would today be a part of the St. Lawrence drainage system.

The possibility of such continued enlargement, however, was denied because that same ice front had been confining a higher and far larger lake on the north side of the Ranges, which abruptly began discharging southward into Lake Merrimac when the eastern end of the Ranges was freed by the retreating ice front.

Lake Wisconsin, largest of all such water bodies within the state, was formed when the advancing Green Bay lobe closed the Devils Lake gap in the South Range. Glacial ice and glacially ponded water then largely replaced the former free drainage of the upper Wisconsin River through this gap. This large lake found an outlet down Black River to the Mississippi north of LaCrosse. Because the ice built a bulky moraine (Johnstown) in two places across the Devils Lake gap, effectively blocking it against re-use by Wisconsin River after retreat from this position, Lake Wisconsin continued to exist and was enlarged eastward as the ice edge shrank back, until the abrupt east-pointing prow where the Ranges join and terminate was ice-free.

With lower surfaces thus exposed the glacial damming of Lake Wisconsin came to an end. The level of the new outlet around the east end of the upland was about 120 feet lower than that leading to Black River. The first 80 feet of this marked drop in level involved the entire lake. There then emerged a high place in the lake bottom, a group of submerged hills of sandstone in the region of The Dells, 20 miles northwest of the new outlet. They became a far more durable dam than glacial deposits could be and held back a large portion of the lake from further abrupt lowering. The

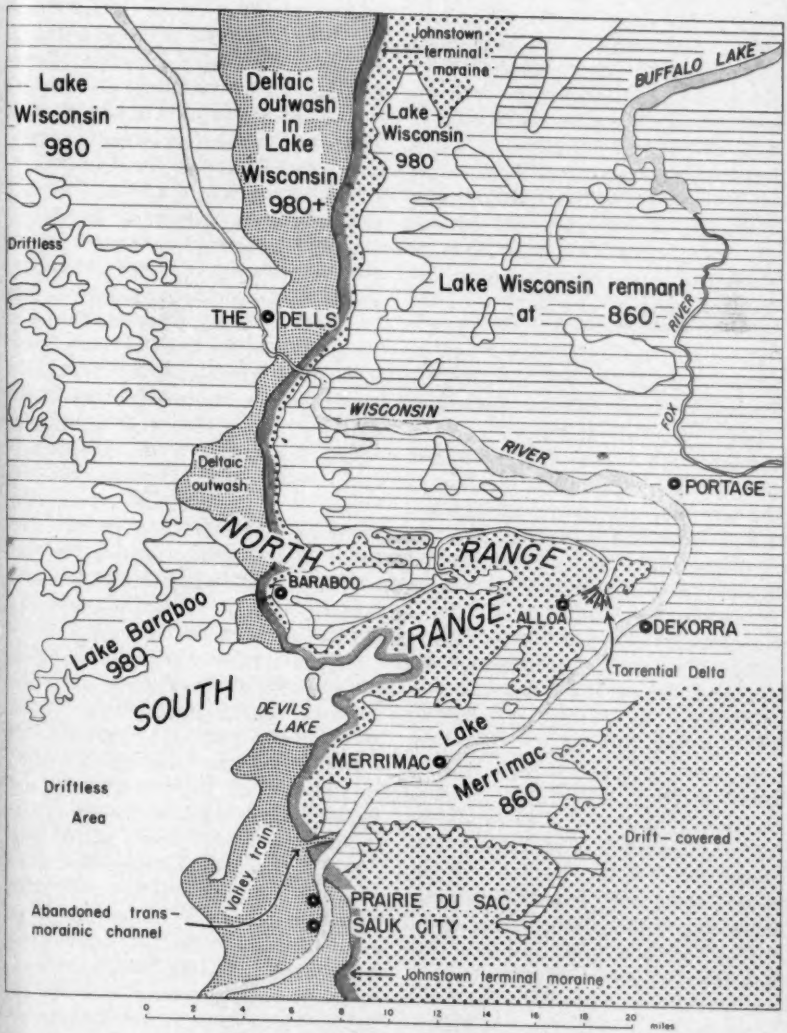

FIG. 1.—Glacial Lake Merrimac

postglacial Wisconsin River is still at work incising this barrier on which it found itself superposed.

The southern and southeastern part of the dismembered lake, however, continued to lower rapidly as obstructing drift deposits were eroded by the new outlet. The details of lowering involved the existence of Lake Merrimac, into which the discharge poured at the time the glacial dam failed, the building of a torrential delta at the head of that lake by the rapid lowering of Lake Wisconsin, followed immediately by the trenching of this delta as Lake Merrimac's own outlet near Prairie du Sac was rapidly deepened and its level lowered by the greatly increased volume of its discharge.

The details are as follows: When retreat south of the Ranges began, an extensive valley train heading at the terminal moraine reached down the Wisconsin valley across the Driftless Area. Where it rested against the outer face of the Johnstown moraine its altitude ranged between 860 and 880 feet A.T., and its gradient thence down-valley was gentle. Rather than the moraine, this valley train was the effective dam for Lake Merrimac. Two channels were promptly cut into the moraine to the level of the outwash apron in front, one now deeply incised by later use and carrying Wisconsin River today, the other a narrow abandoned trench somewhat more than a mile long, exceeding 80 feet in depth and its floor 30 to 40 feet lower than the 850-860 level of the lake.

No shore lines of Lake Merrimac are known, and the only record of the lake's level is the torrential delta east of Alloa and just south of the east end of the Ranges. Its surface is somewhat undulatory, its southern or frontal slope is rudely parallel with the foresets revealed in excavations and its back slope is steep and irregular as befits an ice contact. An alluvial fan stands on the northern part of the delta top, sloping southward and truncated on the north by the same ice contact slope.

Topography alone would hardly establish the interpretation given this hill. There is no denying it, however, when the sections in the gravel pit on the south slope are examined. For 40 or more vertical feet, unbroken foresets of extraordinarily open-work coarse gravel dip southward. Except for one growing delta at the head of Franz Josef fiord, East Greenland, the writer has never seen a more bouldery delta deposit. Most of the boulders are crystallines up to 3, 4, and even 5 feet in maximum diameter. Most of them lie in a cobble gravel; a few are imbedded in pebble gravel. No foresets composed dominantly of boulders were seen, nor any foresets largely of sand. Subordinate to the crystallines are sandstone and dolomite boulders, and still less common but highly significant are widely distributed cobbles and boulders of a pink clayey till. The largest till boulder seen was 3 feet in diameter.

Although all these boulders must have been rolled across the top of the delta to reach the foresets where they rest, there is no channel leading to this delta, no adequately extensive drift surface high enough to have carried a free-surface stream to the delta head. The ice contact slope, if correctly interpreted, records the debouching of the torrential stream directly from the retreating ice front.

The very brief episode of discharge was neither preceded nor followed by any noteworthy outwash

deposition. It therefore appears to record unusual and short-lived conditions that developed just before the ice withdrew from contact with the Ranges. There is strong suggestion that the discharge initiated failure of the ice barrier between lakes Wisconsin and Merrimac, that the hydrostatic head of 120 feet caused a leakage under and through crevasses in the decaying glacial front. The till cobbles and boulders are difficult to explain unless they record quarrying beneath the ice and a very short transportation *upgrade* downstream.

Comparison with the Gregory Valley delta at the head of Franz Josef fiord is interesting although the argument derived is only by analogy. The observed boulders of this Greenland deposit lie on the delta top, extending to the very edge, and obviously indicating that others have gone over the edge to become a part of the foreset structure. Slabby boulders lie in imbricate positions despite their diameters of several feet, a relationship which the existing Gregory stream is wholly incompetent to produce.

These boulders were traced back to the fairly recent breaking of a glacial dam several miles up the Gregory Valley, behind which was impounded a lake*. Velocity for their transportation was provided by the valley's gradient instead of a hydrostatic head, and they were doubtless swept all along the lower valley by the brief torrent when the dam broke. The delta itself is a normal deposit and only the surface boulders are to be compared with those composing so much of the Alloa deposit.

Although no channel leads to the top of the Alloa delta, there is a glacial river channel trenched some 30 feet deep into its eastern part. This was noted by Thwaites,† who interpreted it as the initial outlet when "the ice margin cleared the east end of the Baraboo Bluffs" and "the level of waters impounded in front of the ice fell from about 980 . . . to about 840 feet." According to the present writer, it is the Alloa delta which records initial discharge, and the channel was made after the ice had been cleared away sufficiently to allow standing water at the subsiding Lake Wisconsin level to reach the ice-contact head of the delta. Thus, although the lower portion of dismembered Lake Wisconsin dropped 120 feet to Lake Merrimac's level during the growth of the Alloa delta, no debacle occurred during this failure of the ice barrier at the east end of the Ranges.

Excavation of the channel was completed while the retreating glacial front stood less than three miles to the east. At that distance, the drift surface beneath the glacier was close to 800 feet A. T., and when it became exposed, the channel was abandoned and lakes Merrimac and Wisconsin came to the same level, connected by a strait 4 to 5 miles south of Portage.

But Lake Merrimac was lowered about 30 feet during the channel's life, by reason of the great increase in its discharge volume across the moraine and outwash near Prairie du Sac. The time involved was only that required for about three miles of glacial retreat, a few centuries at the most. In the fact that the delta records none of this lowering, we find additional support for the concept that the extraordinary conditions (penetration of the glacial bar-

* Boyd, L. A. "The Fiord Region of East Greenland," Am. Geogr. Soc. Spec. Publ. No. 18, pp. 185-193.

† Thwaites, F. T. "Pleistocene of part of northeastern Wisconsin," Geol. Soc. America, Bull. Vol. 54, 1943, p. 120.

rier by water under high pressure) produced an extraordinary volume of discharge for an extraordinarily short time.

The two competing transmorainic channels near Prairie du Sac continued to be deepened after lakes Wisconsin and Merrimac became confluent, but the northern one was shortly abandoned and all subsequent drainage, including that from both Early and Late Oshkosh in Fox River drainage, has continued to deepen the winner in the contest, the present Wisconsin River route past Prairie du Sac and Sauk City. Lake Merrimac slowly dwindled to a series of extensive marshes which now are largely submerged beneath an artificial lake back of the power dam at the moraine transection north of Prairie du Sac.

CURRENT EVALUATION OF THE CAMBRIAN-KEWEENAWAN BOUNDARY[1]

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In the Lake Superior region the youngest of pre-Cambrian sequences is the Keweenawan system, 30,000 to 60,000 feet thick; of this system the youngest unit which appears universally recognized as undoubtedly Algonkian is the 12,600 foot Freda sandstone of the Upper Keweenawan Oronto group.

South of the Lake Superior region in the Upper Mississippi Valley, the oldest of recognized Paleozoic sequences is the Upper Cambrian, Croixan Series; of this, the oldest unit universally conceded to be Paleozoic in age is the Mt. Simon sandstone member[2] of the Dresbach formation.

In a kind of no-mans-land of controversy between the obviously Keweenawan units and obviously Croixan units is a group of redbed sandstones and shales ranging up to 2600 feet in thickness, to which Thwaites (1912) applied the term Bayfield group. It now seems highly probable, especially as the result of the heavy mineral studies by Tyler and Thiel (1940), that the Wisconsin Bayfield is represented in Minnesota by similar sediments, there referred to as Red Clastics, Fond du Lac, or Hinckley, and in Michigan by the Jacobsville sandstone. It is the age relations of these units, then, that come into question. The term Bayfield, when used below, is employed as embracing all of them.

Broader regional relations.—The problem fundamentally is whether the Bayfield group is structurally, stratigraphically, and in time more closely associated (1) with the Keweenawan, Oronto group, (2) the Cambrian, Croixan series, or (3) independent of either.

The distribution of strata belonging to the Oronto group, as indicated in figure 1, is confined to the inner portion of the Lake Superior Basin. The distribution of Bayfield strata areally is much more extensive and not necessarily related to the distribution of the Oronto group. The two groups occur together only in the Lake Superior region, and it is this writer's opinion that the occurrence is coincidental. The two sequences occur together *in the same outcrop* at only two localities (Thwaites, 1912): on the south fork of Fish Creek, near Ashland Junction, Bayfield County, and on Middle River in eastern Douglas County, both in Wisconsin. In both instances they occur in the drag zone along the Douglas thrust fault, and/or its eastern extension (fig. 8).

The basal contact of the older, Oronto group is in all cases with the immediately preceding Middle Keweenawan eruptives. The upper contact of the Oronto group is known only from the two localities cited and probably also from deep wells at Ashland, Wisconsin (Thwaites, 1912, p. 65), and Stillwater, Minnesota (Hall et al., 1911; Thwaites, 1931, etc.).

At the two outcrops conformability has been claimed, but since the

[1] Published by permission of the Chief, Illinois State Geological Survey.
[2] The Illinois Geological Survey regards the Mt. Simon as a separate formation rather than a member of the Dresbach formation.

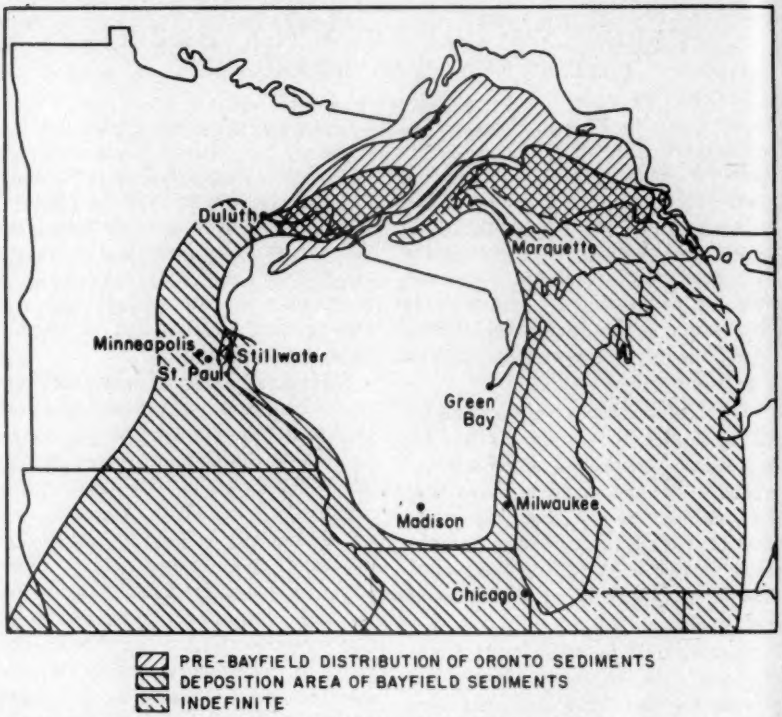

FIG. 1.—Regional Distribution of Oronto and Bayfield Sediments.

strata stand nearly vertical, this appearance of conformability can be misleading, as pointed out by Van Hise and Leith (1911) in connection with Keweenawan-Huronian relations under similar conditions. Furthermore, in the area of the two outcrops and the Ashland well, the attitude of the Oronto beds, lying as they did in the center of the broad Lake Superior syncline, should have been nearly horizontal at the time the Bayfield sediments were deposited on them. Such concordance of strata does not necessarily imply close age relations.

Furthermore, when we consider the regional relations of the Bayfield group, we find that, whereas in a very limited area it is in basal contact with the Oronto sandstone, over a far greater extent it rests nonconformably and in a relatively horizontal attitude on a basement complex of pre-Keweenawan gneisses, schists, and slates, cut by acid and basic plutonics and dike rocks of both Keweenawan and pre-Keweenawan age. The upper contact of the Bayfield, on the other hand, is everywhere with the white sandstone of the Mt. Simon member of the Dresbach formation and the Dresbach and Bayfield maintain conformable relations over all the Upper Mississippi Valley[3] and Upper Great Lakes regions. The dif-

[3] In Illinois no basis has been found for separating the Bayfield and Mt. Simon sandstones, and the Illinois Geological Survey classifies all the sandstone between the pre-Cambrian crystallines and the Eau Claire formation as the Mt. Simon formation of Upper Cambrian age (Templeton, 1950).

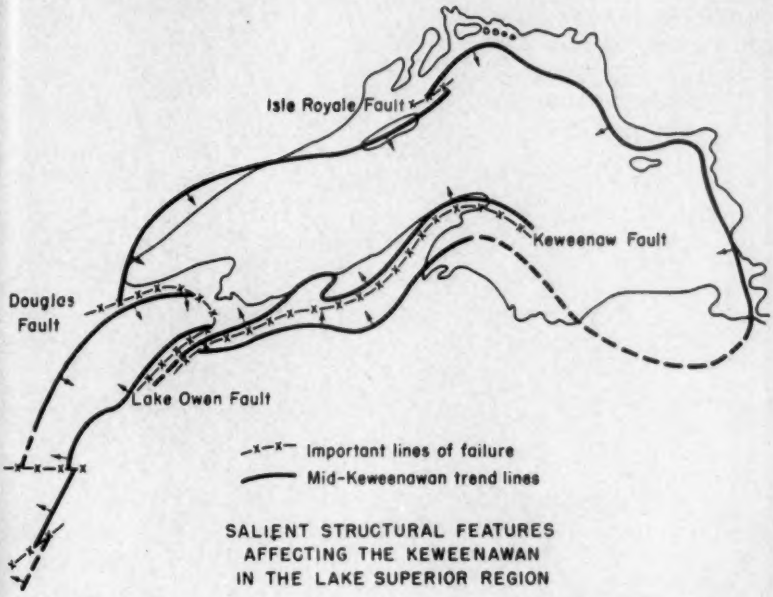

FIG. 2.—Salient Structural Features Affecting the Keweenawan in the Lake Superior Region.

ficulties indicated by Schwartz (1936, pp. 24-25) and others in drawing Red Clastic and Hinckley and Mt. Simon boundaries in the subsurface suggest a high probability that the three units are gradational as well as conformable.

These broad and simple relations might seem to leave no doubt that the age relations of the Bayfield group are with the Cambrian but for the troublesome intervention of seemingly local phenomena, some of which at first glance appear to preclude a Cambrian age. A reassessment of these seeming anomalies is the primary objective of this paper.

ANOMALIES OPPOSING CAMBRIAN ASSIGNMENT OF BAYFIELD

Pre-Cambrian faults.—Those favoring a pre-Cambrian age for the Bayfield stress the fact that in Wisconsin, Minnesota, and Michigan, the Bayfield along with the Oronto is cut by great thrust faults which moved parallel to the dip of the fault plane. They interpret these movements as a part of the orogeny which closed the Algonkian.

That the Bayfield and Oronto are jointly cut by extensive faulting along the Douglas Fault in Wisconsin cannot be denied (see Thwaites, 1912). However, the requirements

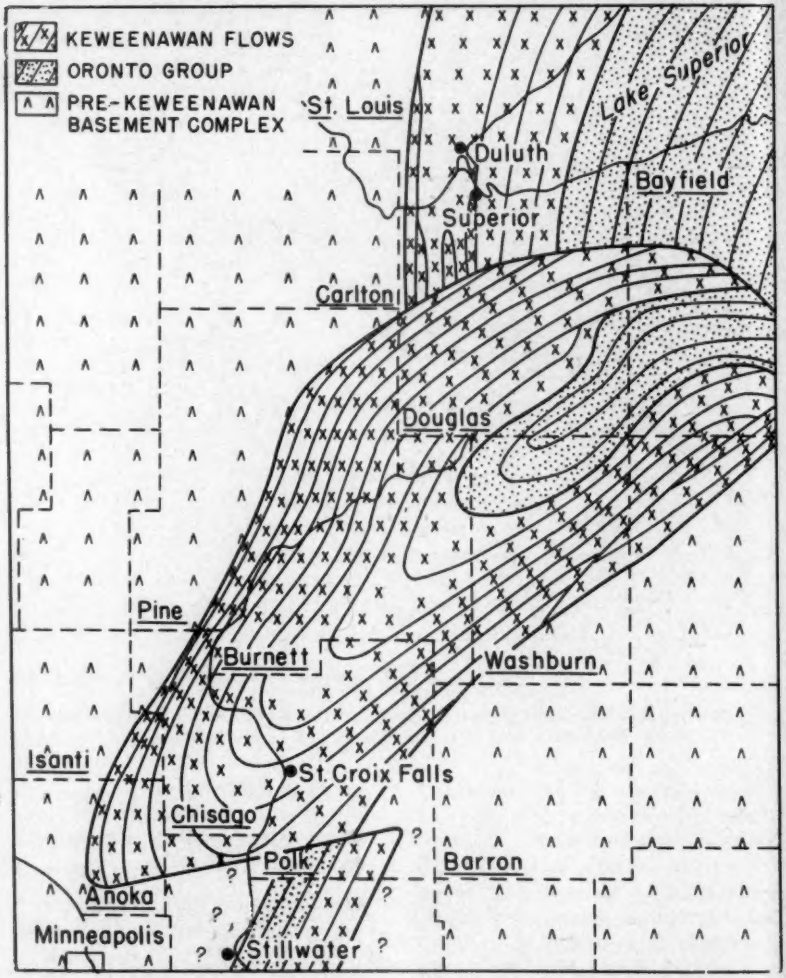

FIG. 3.—Pre-Bayfield Bedrock Surface in West Part of Lake Superior Region.

to account for the type of late pre-Cambrian movements which sheared and disrupted the Lake Superior syncline are, not movements parallel to the dip of the fault plane, but extensive horizontal displacements, north of east, measurable in miles along the Douglas thrust, with only a moderate degree of vertical component. The accompanying map (fig. 2) shows that this latter type of movement must have taken place, and that a thrust block, bounded laterally by the Douglas and Lake Owen faults, respectively, did so move in pre-Bayfield time. However, the present attitude of the Bayfield beds along the fault (and of the

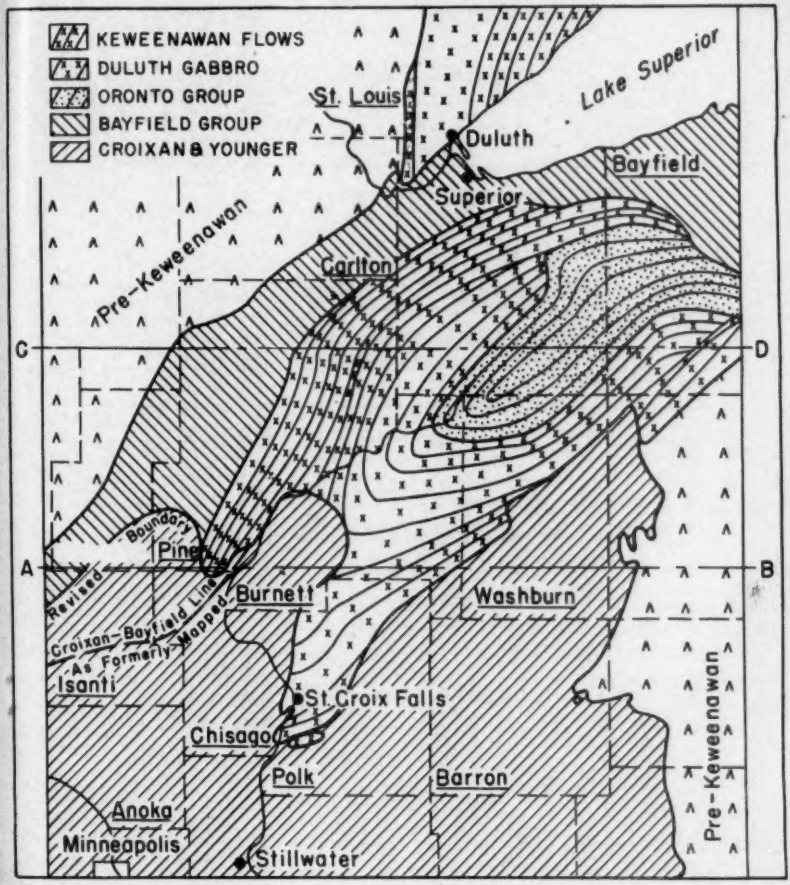

FIG. 4.—Croixan (Bayfield)-Keweenawan Areal Relations in West Part of Lake Superior Region.

Oronto beds dragged up along with them) indicates an extensive thrust movement parallel to the dip of the fault plane with a vertical component of close to 3000 feet of displacement.

That there have been two movements, one pre-Bayfield and one post-Bayfield, seems clear from both regional and local considerations.

In Wisconsin, no evidence is at hand that will permit the dating of the second (post-Bayfield) movement along the old thrust plane. Like the Douglas fault, the Keweenaw fault in Michigan appears to have been pre-Bayfield in origin with postulated secondary movement that, on the downthrust southeastern side, visibly cuts only Jacobsville (Bayfield) beds. But at Limestone Mountain, only a few miles southeast, an isolated outlier of Ordovician, Silurian, and possibly Devonian beds

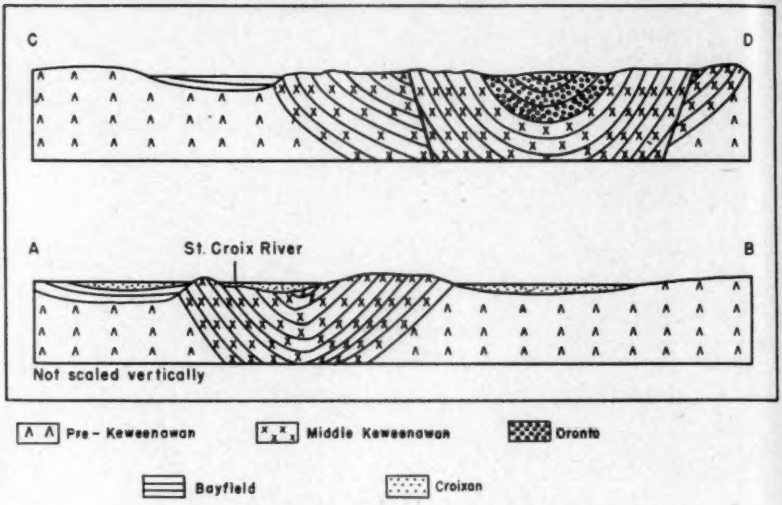

FIG. 5.—Cross Sections Along Lines A-B and C-D of Figure 4.

(Case and Robinson, 1915; Thwaites, 1943) is profoundly shattered by structural movements that can most logically be assumed to be simultaneous with the second period of movement along the Douglas and Keweenaw fault planes.

Douglas fault in Minnesota.—In Minnesota, the structural evidence is less clear and the seeming anomalies more numerous. It has been rather generally assumed that the Douglas fault swings southerly soon after entering Minnesota and continues until lost under glacial drift and/or Paleozoic cover. Unfortunately, the trap-sandstone contact, clearly shown by numerous exposures to be a fault in Wisconsin, is not exposed in Minnesota. Indirect evidence supporting a fault relationship between Bayfield-type sandstone and Keweenawan extrusives seems less than conclusive to the writer. This evidence revolves around two localities, Kettle River and Pine City.

On Kettle River, both Irving (1883, pp. 244-246, figs. 8 and 9, pl. 14) and Upham (1888, pl. 55) describe, map, and illustrate the Hinckley-trap contact in a manner to indicate a nonconformity and a sedimentational contact of horizontal sandstone on steeply dipping lavas. But C. W. Hall (1901, pp. 324-325) states: "Along the entire distance of the contact, the attitude of the sandstone is that of a greatly disturbed formation; it is broken in places in blocks, some of them of huge dimensions lying in many different directions. They have every appearance of being shattered by profound crustal movements." Here is obviously an area calling for further detailed study.

At the Pine City locality, very steeply eastward-dipping lavas outcrop in Snake River at the outlet of Cross Lake, whereas a well drilled scarcely a mile to the west encountered no lava and terminated at a depth of 700 feet in red sandstone. This relationship, plotted on a twen-

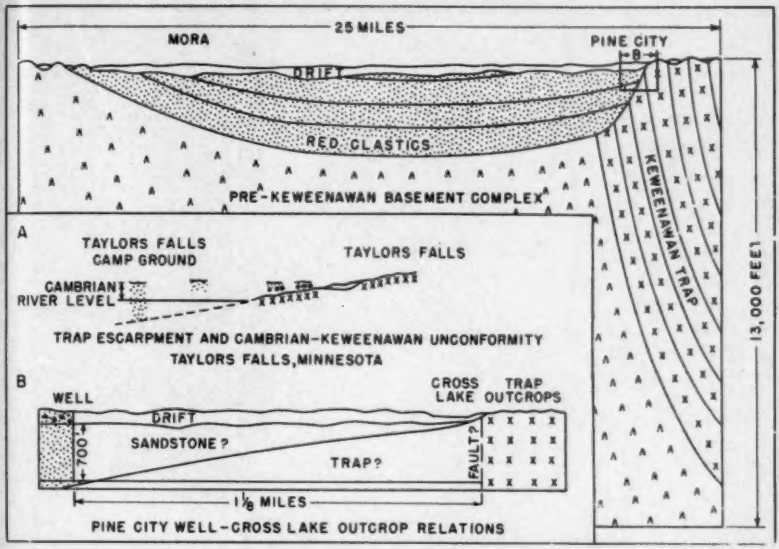

FIG. 6.—Postulated Bayfield-Keweenawan Relations in the Pine City-Mora Area.
a. Actual Pre-Croixan Erosian Surface Profile at Taylors Falls, Minn.
b. Postulated Pre-Bayfield Erosion Surface Profile in Pine City Area, on Scale 1:1.

ty-to-one exaggeration by Thiel (1947, p. 194) gives thus a relief that seems to demand a fault postulate. However, the same relationship plotted on a one-to-one scale by the writer (fig. 6b) compares very closely with the slope of the trap-sandstone contact exposed at Taylors Falls, Minnesota (fig. 6a), a place where the sedimentational nature of the contact is demonstrable and the Cambrian age of the sandstone unquestioned.

Gravity-meter evidence.—G. I. Welch (1941) published the result of a gravity-meter traverse across the lava-sandstone contact a short distance south of the Pine City well. The observed anomaly he interprets as indicative of a fault of about 11,000 foot displacement.

Actually Welch's data do not constitute proof of the existence of a fault at this place. According to his interpretation, which assumes (1) that there is a fault and (2) that the upthrown side of the fault is all trap and the downthrown side is sandstone on trap, then the anomaly shows that 11,000 feet of sandstone is present on the downthrown side of the postulated fault.

If, on the other hand, there be postulated a situation as illustrated in figure 6, the recorded gravity anomaly reflects quite different conditions which do not necessarily involve faulting. Let us assume the sandstone sequence to be approximately 2000 feet thick, normal for the Hinckley-Red Clastic succession. Let us further assume that to the east the sandstone abuts the Keweenawan lava along a steep pre-Bayfield erosional slope similar to the pre-Croixan erosional slope at St.

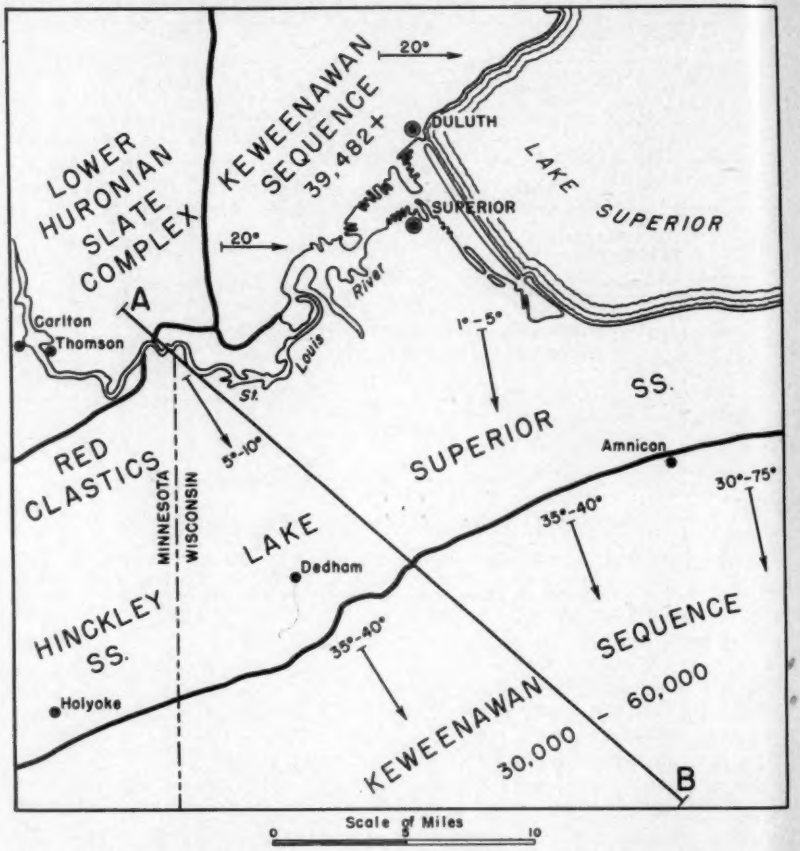

FIG. 7.—Dip-strike Relations of Keweenawan Sequence and Bayfield Equivalents at West End of Lake Superior.

Croix Falls. Finally, concealed beneath the sandstone is a steeply dipping contact between the highly inclined lavas to the east which represent the west limb of the Lake Superior syncline and the pre-Keweenawan complex of granites, gneisses, schists, slates, etc., to the west. The gravity anomaly may thus be a consequence of a line between a western belt of sandstone on various crystallines of lesser density than diabase and an eastern belt of dense diabase extrusives. The steep westerly sloping contact between lava and sandstone and the steep easterly sloping contact between lava and basement complex might well combine to resolve a sharp line of gravitational anomaly. This is not to say that faulting of limited extent may not incidentally be associated with this zone.

Tilting of Bayfield strata.—The facts that the Red Clastics in Minnesota dip at angles up to 10° and the

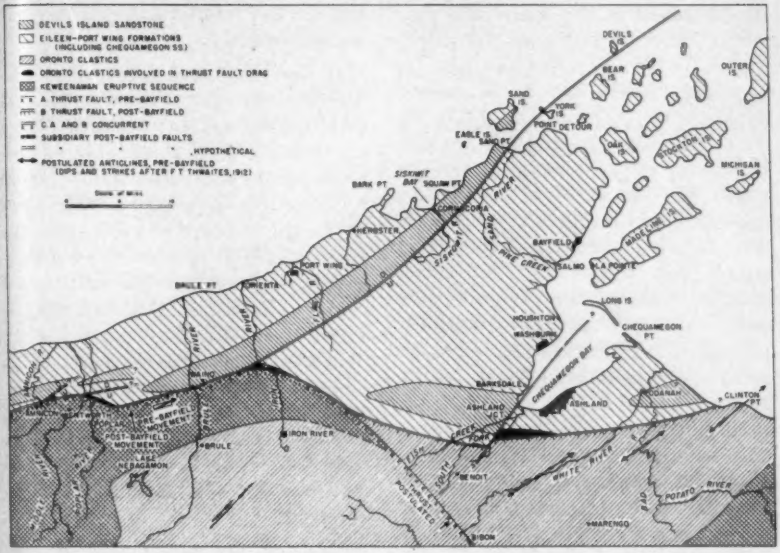

FIG. 8.—Postulated Pre- and Post-Bayfield Fault Patterns in the Bayfield Type Area.

overlying Hinckley sandstone dips commonly from 1°-2°, whereas the St. Croixan beds to south and east are essentially flat-lying, have been cited (Atwater and Clement, 1935) as evidence for the pre-Cambrian age of the Hinckley-Red Clastics (fig. 7). The increase in dip downward in the sequence may be a reflection of initial dip of the basal beds close to the contact with the basement complex; but the writer interprets it to be a consequence mainly of regional uplift of the country lying to the northwest and north of the Hinckley-Red Clastic belt of outcrop (figs. 3, 4, and 5).

That such a regional rise did take place is suggested by the contrast between Bayfield relations in southern Minnesota and in east central Minnesota. In the former area, the Bayfield equivalents in the subsurface are flat-lying, uniform in thickness over a wide area, and conformably overlapped westward by the Dresbach against the granite basement (Hall et al., 1911, pl. V; Couser, C. W., 1935). In the latter area, on the other hand, observable dips are present in sandstones of Bayfield age, outliers occur well beyond the main outcrop belt, and the strata, along with the overlying Croixan beds, have been truncated by erosion (figs. 5, 6, and 7).

Light mineral data. — Atwater (1935, p. 318) considered that the Hinckley sandstone could be distinguished from the Mt. Simon (Croixan) on the basis of secondary enlargement of quartz grains in the latter formation. However, secondary enlargement of quartz has been noted in some Croixan sandstones as well.

Association with diabase.—Hall et al. (1911, p. 48) cite the association

of diabase with red sandstones in a well at Stillwater, Minnesota, as evidence for the Keweenawan age for the Red Clastics of the Minnesota subsurface. Yet of ten Minnesota wells which passed through the redbeds and into pre-Cambrian crystallines (Hall et al., 1911), only this one encountered diabase. Of the remainder, one penetrated quartzite, one "crystalline rock," and seven granite. Except for the Stillwater well, the greatest thicknesses of Hinckley-Red Clastic strata reported in the Minnesota subsurface are at Minneapolis (1200 feet) (Schwartz, 1936, p. 222) and at Mankato (over 1289 feet) (Hall et al., 1911, p. 141). In the Stillwater well, over 2000 feet of redbeds are reported to have been penetrated, above nearly 500 feet of diabase (Hall et al., 1911, p. 366; Thwaites, 1931, pp. 740-742, fig. 3; Stauffer et al., 1935, p. 638). The Stillwater locality is evidently the one place in Minnesota where drilling has encountered Red Clastics underlain by Keweenawan Oronto sandstone, as indicated by the excessive local thickness of the redbeds and association with Middle Keweenawan diabase. This area is in line with the axis of the Lake Superior syncline, and Keweenawan rocks are here to be expected (figs. 1 and 2).

This interpretation removes a serious anomaly from Meinzer's map (Hall et al., 1911, pl. III) showing the elevation of the "pre-Cambrian": that is, the crystalline floor beneath the sediments in Minnesota. In regarding all redbeds as one unit, (pre-Cambrian in age but mapped with the Paleozoic), Meinzer (Hall et al., 1911, pl. III) is forced to contour a deep 2000-foot hole at Stillwater. The writer's reinterpretation of the composite nature of the redbed section here eliminates this peculiar anomaly.

Ordovician-Jacobsville unconformity.—In the Upper Peninsula of Michigan, another seeming anomaly presents itself at the isolated outlier, Limestone Mountain. Here Middle Ordovician Platteville strata lie in concordant dip not far above layers of Jacobsville sandstone with a short concealed belt intervening (Case and Robinson, 1915; Thwaites, 1943). This extensive unconformity has been interpreted to lie between pre-Cambrian and Paleozoic, to indicate the nondeposition of Cambrian and Lower Ordovician rocks in this region, and thus to establish the pre-Cambrian age of the Jacobsville.

However, an examination of relationships in the eastern part of the Upper Peninsula and southward along the west shore of Lake Michigan reveals that the time of erosion was not between the Bayfield and the Croixan, but between Middle and Lower Ordovician (Thwaites, 1923, 1927, 1934, 1943). Truncation of the pre-Chazyan beds cuts progressively deeper as one goes westward from the upper end of Lake Michigan, and also as one goes northward. The extreme case of depth of pre-Middle Ordovician erosion in Wisconsin-Michigan is at Limestone Mountain where Mohawkian strata rest on the Bayfield.

Lack of Chequamegon equivalent in Minnesota.—The problem of the correlation of Thwaites' Chequamegon formation constitutes another seeming anomaly. To recapitulate, Thwaites (1912) divided the Wisconsin Bayfield group into three formations in descending order as follows:

Chequamegon sandstone	1000 feet
Devils Island sandstone	300 feet
Orienta sandstone	3000 feet
Total	4300 feet

Tyler and Thiel (1940) have shown that the Red Clastics of Minnesota correlate with the Orienta sandstone and the Hinckley correlates with the Devils Island sandstone. But, on top of the Hinckley in Minnesota rests the white Mt. Simon sandstone of Croxian age and upon the Devils Island rests the pre-Croixan, redbed Chequamegon sandstone.

Writers accepting the Wisconsin Bayfield succession at face value (see Thiel, 1940, p. 1516) have regarded this as evidence of a pre-Mt. Simon unconformity involving the loss in Minnesota of 1000 feet of strata. Yet, an abundance of deep well data from that state also seems to indicate that Hinckley-Mt. Simon relations there are clearly gradational.

A critical examination of the evidence on which Thwaites (1912) established his Chequamegon formation reveals a probable resolution of this paradox, namely that Thwaites' Chequamegon brownstone formation is none other than the Port Wing brownstone member of the Orienta formation, repeated by faulting (fig. 8). The contact of the Chequamegon formation with the supposedly underlying Devils Island formation is reported by Thwaites only from the type locality, Devils Island. The beds here that he considers to be Chequamegon, he assigns to the "basal Chequamegon" and describes (1912, p. 38) as follows:

At the south end of Devils Island, which is entirely surrounded by a rock cliff, the light-colored basal layers of the Chequamegon sandstone are seen. These are interbedded layers similar to the main body of underlying Devils Island sandstone, so that no very sharp line of demarkation can be seen.

The writer suggests that these layers are a part of the Devils Island formation rather than the Chequamegon brownstone and that a fault contact lies off-shore to the south and there separates the Devils Island from the brownstone that forms the southern islands of the Apostle group. Thwaites' detailed description (1912, pp. 34-35) of the "Quarry" or "Brownstone Beds" of the Chequamegon on the mainland is essentially identical with that of the "Port Wing Brownstone" of the Orienta, while the upper or "Washburn Beds," especially those from the well of the Barksdale Powder Works, are described in much the same terms as his "upper member" of the Orienta formation.

Reinterpretations by the writer reduce the total thickness of the Bayfield group from Thwaites' figure of 4300 feet down to a maximum of 2600 feet, mainly through the dropping of the Chequamegon formation. This gives a figure more in accord with the average regional thickness of the subsurface Bayfield.

The Bayfield and the pre-Cambrian peneplain.—There remains one more point of issue which is in the nature of an argument rather than an anomaly. Proponents of a Keweenawan age assignment for the Bayfield stress the fact that the structural elements that affected it and related sandstones were truncated by the pre-Cambrian peneplain. The writer maintains that beyond the areas of Paleozoic cover, there is

no means of determining the age of the present bedrock surface on the crystallines. It may be close to the pre-Cambrian erosion surface, but may be of later origin or origins. Within the Lake Superior region itself, there is evidence not only of pre-Middle Ordovician, but also of pre-Cretaceous and post-Cretaceous, erosion surfaces (Van Hise and Leith, 1911, p. 178, p. 616, p. 625).

The Silurian beds at Limestone Mountain lie below the postulated pre-Cambrian peneplain surface, as do the Jacobsville and Bayfield strata. There is reason to believe that Silurian strata may formerly have extended widely in the Lake Superior Basin and over much if not all of the Wisconsin Arch, and that the Devonian clearly extended over the latter at least in part. It is not plausible to infer that the erosion which removed these thousands of cubic miles of rock stopped completely when the pre-Cambrian bedrock surface was reached.

Supporting the idea that the original pre-Cambrian erosion surface developed before, not after, the deposition of the Bayfield group is Tyler's (1940, p. 1481) conclusion that the Bayfield sediments differ from those of the Oronto group in such a way as to indicate a marked difference in time and a partial difference in source. Tyler states as follows:

> **The quartzose character of the Bayfield indicates that these sediments were subjected to more mature weathering than those of the Oronto group, and that the Bayfield group may have been derived from previously existing sediments. The most likely sedimentary source for the Bayfield would be the older Oronto series. Their derivation from this source, however, would necessitate almost complete elimination of feldspar, epidote, and garnet of the Oronto sediments and a large decrease in the quantity of ilmenite. It seems more likely that the Bayfield sediments were derived from the Keweenawan sediments or acidic igneous rocks which did not contain large amounts of epidote or ilmenite and that the region from which the garnet was derived during Oronto time had ceased to contribute sediments to this basin of deposition during Bayfield time.**

It seems to the writer that Tyler's evidence does not necessarily indicate a bedrock source low in epidote and ilmenite. Rather it seems to indicate a cycle of deposition independent of and much later than that of the Oronto sedimentation. The latter derived its material from fresh bedrock whereas the Bayfield material seems to have been derived from a mature erosion surface on which the epidote and much of the feldspar was eliminated, and a substantial portion of the ilmenite was altered to leucoxene.

Factors Opposing Keweenawan Age Assignment of Bayfield

Study of the broad field relations has inclined the writer to the opinion that the Bayfield group and its equivalents are more closely related to the Croixan than to the Keweenawan. The present paper has been devoted largely to a review and reduction of the "strong points" which appear to resist a Cambrian assignment for the group. Although a full discussion of the case against a Keweenawan age assignment is not within the scope of this paper, it is appropriate to state that, in the opinion of the writer, the sum of the evidence opposing such an assignment is insuperable. In brief, the following are items of cardinal import to this effect.

1. In places Bayfield equivalents demonstrably rest on pre-Keweenawan strata, as in east-central Minnesota, the Michigan Upper Peninsula, at the east end of Lake

Superior in Ontario, and almost universally in the subsurface; those who would assign a Keweenawan age to the Bayfield must account for the absence by unconformable overlap of from 30,000 to 60,000 feet of pre-Bayfield Keweenawan section. The fact that the 30,000-60,000 feet of earlier strata is so generally missing, with only the "terminal" 2,000-3,000 feet of strata present, fosters the suspicion that we are dealing with two independent sequences.

Whether this absence of 90 to 95 percent of the Keweenawan section at these places be explained as a result of unconformable overlap (Thwaites, 1912; Atwater, 1935, etc.), of faulting (Schwartz, 1949, etc.), or of deposition in postulated grabens (Thwaites, 1943), the minimum local relief involved in any case exceeds the altitude of Mt. Everest (29,002 feet).

The accommodation of the latter concepts becomes most difficult at the west end of Lake Superior. Here, to assign a Keweenawan age to the Fond du Lac, where it rests on the Lower Huronian Thomson Slate complex, it is necessary to account for the disappearance of roughly 55,000 feet of strata (over 10 miles thick) in a narrow gap 10 miles wide, between the North Shore Keweenawan sequence and the South Shore Keweenawan sequence. Either a 55,000 foot mountain ten miles wide, a fault with a 55,000 foot vertical displacement, or pre-Keweenawan grabens 55,000 feet deep must be postulated here to maintain conformability of the Bayfield with the Keweenawan.

If it be necessary to mention additional adverse factors to the Keweenawan age assignment of the Bayfield, there are the following:

2. If, as has been generally credited (Schwartz, 1949, p. 33), the diabasic and basaltic dikes cutting the Huronian complex west of the Hinckley-Red Clastic belt in east-central Minnesota are the dike-roots of eroded Middle Keweenawan flows, then neither the postulate of unconformable overlap nor that of pre-Keweenawan grabens can be maintained; and to maintain the simple fault hypothesis, it is necessary to postulate the removal by erosion of strata considerably in excess of 55,000 feet, west of the fault.

3. Cases where essentially flat-lying strata of Bayfield age surround or lie up-dip from inclined Middle Keweenawan extrusive strata have never been satisfactorily accommodated within a Keweenawan age hypothesis for the Bayfield. Among such cases is Silver Mountain, reported by Irving (1883, p. 202), which is composed of diabase, dipping northwestward 30°, and apparently surrounded by horizontal Jacobsville sandstone. Another which has not been described in detail, is mapped in the Batchawana Bay area of Ontario (Van Hise and Leith, 1911, pl. I).

4. The evidence of the heavy minerals, as reported by Tyler and Thiel (1940), indicates that outstanding differences exist between the suites of the pre-Bayfield and the Bayfield sands. In general the Bayfield suites are more closely comparable with those prevailing in the Mt. Simon and Galesville members of the Croixan Dresbach formation, than with the Keweenawan, and unlike the latter, imply a mature erosion surface at the source.

Interpretation of Bayfield Environment

The writer suggests that the Bayfield sediments are continental de-

posits of Middle and quite possibly also of Early Cambrian age laid down in structural basins formed at or after the close of the Algonkian. The basins in the Lake Superior region were narrow and a consequence of down-faulting along one side, whereas those in southeast Minnesota, in the Lake Michigan region and southward, seem to have been the result of gentle downwarping. Deposition appears at first to have been largely fluviatile (Thwaites, personal communication), passing with increased regional subsidence probably through lacustrine and estuarine conditions (Hinckley and Mt. Simon) with the eventual arrival of marine waters, bringing the Eau Claire faunas to parts of the region.

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THE MT. SIMON SANDSTONE IN NORTHERN ILLINOIS[1]

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Wells in northern Illinois penetrate from 1600 to 2100 feet of upper Cambrian Mt. Simon sandstone between the Eau Claire formation and pre-Cambrian crystallines. In most of the region the sandstone is pure and light colored, but in the vicinity of Boone County all but the uppermost beds are silty, argillaceous, and dark red. The light-colored sandstone long has been correlated with the Mt. Simon formation of northwestern Wisconsin, but recently the red clastics were assigned provisionally to the pre-Cambrian and correlated with the Fond du Lac formation of eastern Minnesota. The present study shows that the red clastics of northern Illinois are a local facies of the light-colored Mt. Simon sandstone. On the basis of differences in grain size, the formation is divisible into seven regionally persistent members. Evidence is presented which suggests that the Mt. Simon sandstone of Minnesota and the upper part of the Mt. Simon at the type locality belong to the Eau Claire formation.

Previous and present studies.—Early subsurface studies in northern Illinois referred all sandstone beneath Eau Claire dolomitic strata to the Mt. Simon, although a possible Keweenawan age for the red clastics at Dixon was suggested (Thwaites, 1923, pp. 534, 553-555). Thwaites' tentative Keweenawan correlation at Dixon was rejected by Knappen (1926, pp. 34-36). In later studies the red clastics of northern Illinois and similar strata in eastern Wisconsin were stated to be of unknown age but were not separated from the Mt. Simon formation (Thwaites, 1931, p. 742; Twenhofel, Raasch and Thwaites, 1935, p. 1693, pl. 151). Possible correlation of the arkosic basal Mt. Simon strata of southern Lee County, Illinois, with the supposedly Keweenawan Hinckley sandstone of eastern Minnesota has been suggested (Payne, 1942, p. 54). Recently the red clastics of northern Illinois were correlated tentatively with the supposedly pre-Cambrian Fond du Lac formation of eastern Minnesota (Bays and others, 1945, p. 1146; Weller and others, 1945), and the regional lithology and thickness of the "Mt. Simon-Fond du Lac (?)" sandstones were summarized (Workman and Bell, 1949, pp. 2041-2043). In the present study all available cuttings from wells in central northern Illinois which penetrated the Mt. Simon and "Fond du Lac (?)" formations were carefully examined, as well as samples from deep borings in part of northeastern Illinois.

Name and definition.—At the type locality the Mt. Simon formation, named from exposures on and near Mt. Simon at Eau Claire, northwestern Wisconsin (Ulrich, 1914, p. 354), consists mainly of coarse-grained, partly conglomeratic, thick-bedded sandstone 234 feet thick, which overlies pre-Cambrian granite and underlies fine-grained thin-bedded *Cedaria*-bearing Eau Claire

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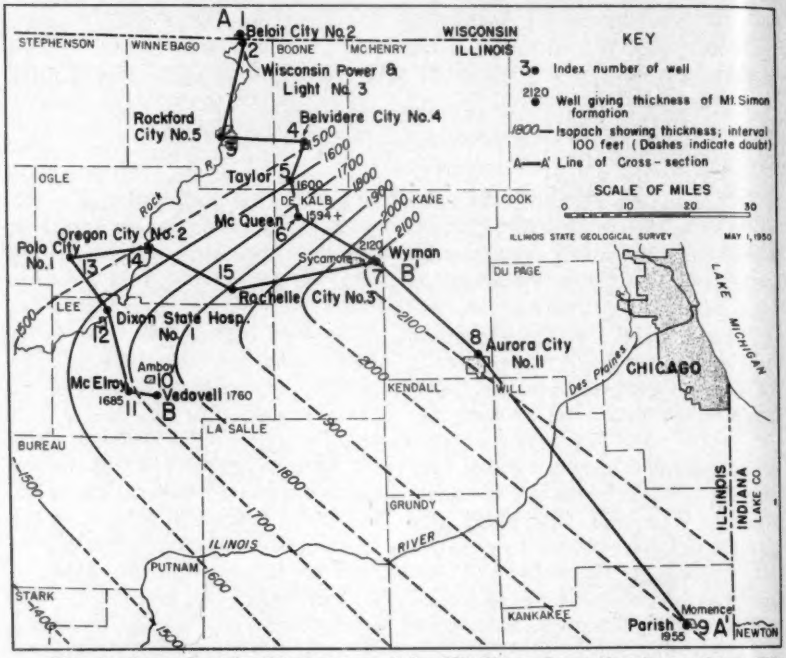

FIG. 1.—Isopach and reference map of the Mt. Simon formation in northern Illinois. (Modified from Workman and Bell, 1948, fig. 4.)

sandstone (Twenhofel, Raasch and Thwaites, 1935, pp. 1693, 1739-1740). In this report the name Mt. Simon is applied to all sandstone between pre-Cambrian crystallines and sediments which are classed as Eau Claire but probably underlie the *Cedaria* zone.

Thickness.—In northern Illinois only four wells (fig. 1, wells 5, 7, 10, 11) have completely penetrated the Mt. Simon sandstone, although two other wells (6, 9) are believed to have passed almost through the formation. The sandstone is thickest in a basin extending from DeKalb to Cook counties in northeastern Illinois and attains a maximum known thickness of 2120 feet in northeastern DeKalb County. From this area it thins rapidly to thicknesses of 400 feet or less in most of the states surrounding Illinois, and lenses out in northeastern Wisconsin and southwestern Ontario (Cohee, 1945, 1948).

Lithology.—In northern Illinois the Mt. Simon sandstone is divisible into a light-colored facies, which constitutes the bulk of the formation in most of the region, and a red facies, which is best developed at Belvidere, Boone County. Much gradation and interfingering characterize the transition zone between the two facies, which in places is less than 6 miles wide (fig. 2, wells 4, 5). Both facies are nonfossiliferous.

Light-colored facies.—The light-colored Mt. Simon facies is white, yellow, or pink to light brown. The sandstone ranges from very fine to very coarse grained and locally is silty. Much of it is conglomeratic, containing quartz granules from 2 to 4 mm. in diameter and quartz peb-

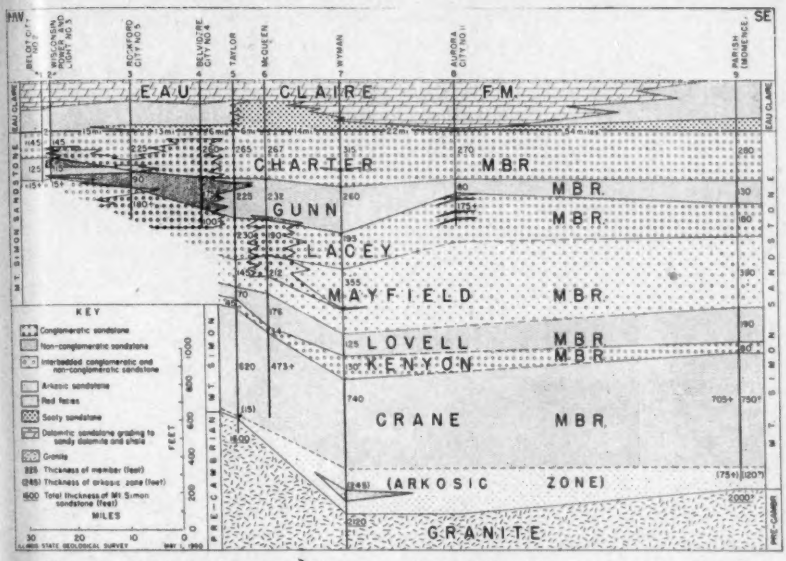

FIG. 2.—Northwest-southeast cross section of the Mt. Simon formation from Beloit, Wisconsin, to Momence, Illinois. (Line A-A', fig. 1.)

bles from 4 to 8 mm. in diameter. As a whole the sandstone is coarser grained than any other in northern Illinois. Sorting generally is poor, but some well-sorted beds are present. Although the grains range from angular to well rounded, they are chiefly subangular. The granules and pebbles are well rounded. Most of the sandstone is incoherent, but thin layers have been cemented by iron oxide or silica. A zone varying from 15 to 249 feet thick at the base of the formation is arkosic and locally contains biotite and muscovite flakes as well as granite grains and pebbles. Occasional grains of feldspar and granite and very rare gabbro and quartzite pebbles have been observed in higher beds. Thin layers of dark-red or variegated, partly micaceous shale and siltstone occur at different horizons.

Red facies.—Where best developed the red facies is characterized by large amounts of disseminated dark-red hematitic clay and silt and by the presence of relatively thick interbeds of dark-red, partly micaceous, partly sandy shale and siltstone. Where weakly developed, as in southern Lee County, the facies is distinguished mainly by hematitic films on the sand grains.

Subdivision into members. — Throughout northern Illinois the Mt. Simon sandstone consists of a cyclic alternation of relatively fine-grained units and coarse-grained, granule-bearing units (figs. 2, 3). Although to the southeastward and westward granules become scarcer and smaller, and the entire formation grows more silty and finer grained, the sequence still is clearly distinguishable. Some lateral gradation or interfingering may take place along the contacts between the units. The seven major units present are herein regarded as members, and are

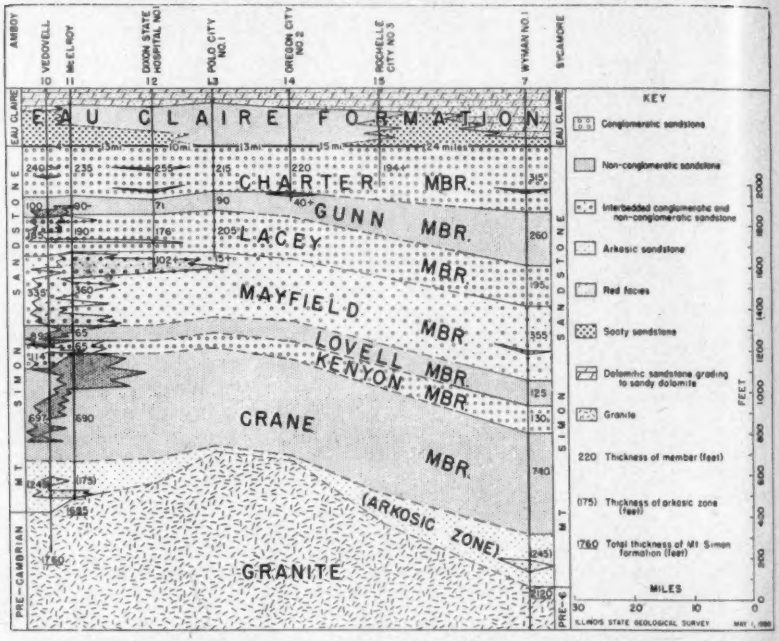

FIG. 3.—Cross section of the Mt. Simon formation from the vicinity of Amboy, Illinois, to the vicinity of Sycamore, Illinois. (Line B-B', fig. 1.)

named and described in ascending order. The members are made up of numerous subordinate units, many of which extend practically throughout the region.

The type well for the four lower members is Wyman No. 1 (well 7), a cable-tool well in the NE¼ NE¼ SE¼ Sec. 35, T. 41 N., R. 5 E., DeKalb County, Illinois, sample set 1301.[2] The type well for the three upper members is McQueen No. 1 (well 6), a cable-tool well in the SW¼ NE¼ NE¼ Sec. 27, T. 42 N., R. 3 E., DeKalb County, Illinois, sample set 1466.

Crane member.—For the relatively fine-grained basal member of the Mt. Simon formation the name Crane member is proposed. The name is derived from the Crane School, NW¼ NE¼ NW¼ Sec. 22, T. 40 N., R. 5 E. DeKalb County, 4 miles south of the type well. The "type section" consists of samples 387 through 491 in sample set 1301, extending from depths of 3105 to 3845 feet. The member ranges from 620 to 740 feet thick (figs. 2, 3). The grains range from very fine to very coarse, and a few granules are rarely present, but the predominant grades are fine and medium. The lower portion of the member generally is more or less shaly, silty, and arkosic.

Kenyon member.—For the thin conglomeratic sandstone overlying the Crane member the name Kenyon member is proposed. The name is derived from Kenyon school, NE¼ NW¼ NW¼ Sec. 17, T. 40 N., R. 6 E., Kane County, 3¼ miles south-

[2] Number of sample set in subsurface files of Illinois Geological Survey. Most samples in both sets represent five- or ten-foot intervals.

east of the type well. The "type section" consists of samples 367 through 386 in sample set 1301, extending from depths of 2975 to 3105 feet. The member ranges in thickness from 34 to 130 feet. Where less than 80 feet thick, it is composed chiefly of coarse-grained sandstone containing quartz granules, but where thicker it consists of conglomeratic sandstone interbedded with nonconglomeratic layers.

Lovell member.—The succeeding relatively fine-grained unit is here named the Lovell member for Lovell School, SW¼ NW¼ NE¼ Sec. 2, T. 40 N., R. 5 E., DeKalb County, three-quarters of a mile southward from the type well. The "type section" consists of samples 348 through 366 in sample set 1301, extending from depths of 2850 to 2975 feet. In thickness the member varies from 65 to 190 feet. Although grain sizes range from very fine to very coarse, the predominant grade is fine or medium. In the McElroy well (11) the member is partly coarse grained to conglomeratic but is clearly separable from the adjacent coarser-grained units.

Mayfield member.—Overlying the Lovell member is a thick sequence of interbedded conglomeratic and nonconglomeratic sandstones for which the name Mayfield member is proposed. The name is obtained from Mayfield Township, T. 41 N., R. 4 E., DeKalb County, Illinois, 5 miles west of the type well. The "type section" consists of samples 300 through 347 in sample set 1301, extending from depths of 2495 to 2850 feet. The thickness of the member ranges from 145 to 390 feet. The units composed of very coarse-grained to conglomeratic sandstone are from 5 to 125 feet thick; those made up of finer-grained nonconglomeratic sandstone are from 10 to 90 feet thick. In the McElroy well (11) most of the sequence is conglomeratic, but in the Taylor and Parish wells (5, 9) granule beds are very subordinate.

Lacey member.—The fifth Mt. Simon member consists principally of conglomeratic sandstone. It is here named the Lacey member from Lacey School, NW¼ NW¼ NW¼ Sec. 31, T. 42 N., R. 4 E., DeKalb County, 2½ miles east of the type well. The "type section" consists of samples 257 through 278, in sample set 1466, extending from depths of 1880 to 2070 feet. The thickness of the unit ranges from 176 to 230 feet. In most wells a bed or beds of comparatively fine-grained nonconglomeratic sandstone are present in the middle of the member, and in the Parish and McElroy wells (9, 11) interbeds of fine-grained sandstone occur in the lower part of the unit. Red shale layers commonly are more abundant in the Lacey and higher members than in the underlying strata.

Gunn member.—The Lacey member is overlain by a relatively fine-grained unit here named the Gunn member from Gunn School, NW¼ NW¼ NW¼ Sec. 16, T. 42 N., R. 3 E., DeKalb County, 2¾ miles northwest of the type well. The "type section" consists of samples 234 through 256 in sample set 1466, extending from depths of 1648 to 1880 feet. In thickness the member varies from 71 to 260 feet. The grain size ranges from very fine to very coarse, and a few thin beds of granule conglomerate generally are present. However, the grain size is conspicuously finer than in the adjacent members, and in several wells the dominant grade is fine.

Charter member — The coarse-grained to conglomeratic uppermost member of the Mt. Simon formation is here named Charter from Charter Oak School, SE¼ SE¼ SE¼ Sec. 2, T. 42 N., R. 3 E., DeKalb County, 3½ miles north of the type well. The "type section" consists of samples 204 through 233 in sample set 1466, extending from depths of 1381 to 1648 feet. The member ranges from 145 feet to 315 feet thick. In some wells it is composed almost entirely of very fine- to very coarse-grained sandstone which is mainly coarse grained and has one or more thin layers of granule conglomerate. In other wells conglomeratic sandstone makes up most of the member.

Stratigraphic relations.— The Mt. Simon sandstone rests unconformably on a pre-Cambrian basement complex. Where it has been penetrated by wells in northern Illinois, the complex consists of granite with local felsite dikes (Grogan, 1949). The Mt. Simon is overlain by the Eau Claire formation with apparent conformity in both Wisconsin and Illinois (Twenhofel, Raasch and Thwaites, 1935, pp. 1693-1696, 1714-1715).

Correlation.—In Kane County, northeastern Illinois, the basal two-fifths of the Eau Claire formation is composed mainly of sandy dolomite and shale which contains oboloid brachiopods in the lower half (fig. 2). Westward these beds grade laterally into gray, very fine- to coarse-grained sandstone which is given a sooty aspect by encrusting particles of black pyrite (Workman and Bell, 1949, pp. 2043-2049). The sooty sandstone extends into western Illinois and northward to Winnebago County. However, before reaching Beloit, Wisconsin, it passes laterally into light yellow sandstone which is distinguished from the underlying Mt. Simon sandstone by its finer grain-size and the absence of granules. Both the sooty and the yellow sandstone locally contain oboloid brachiopod fragments.

At the type section in Wisconsin the Mt. Simon sandstone shows the following sequence from the base upward: (1) granule-bearing, 3 feet, (2) without granules, 28 feet, (3) granule-bearing, 108 feet, and (4) without granules and containing oboloid brachiopod fragments, 95 feet (Twenhofel, Raasch and Thwaites, 1935, pp. 1739-1740). It is thought most likely that units 1 through 3 correspond, respectively, to the Lacey, Gunn, and Charter members and that unit 4 is equivalent to the basal Eau Claire sandstone of northern Illinois. Definite correlations must await detailed surface and subsurface tracing between Beloit and Eau Claire, Wisconsin. However, if this interpretation is correct, it would appear desirable to include unit 4 of the Mt. Simon type section in the Eau Claire formation because this unit (1) can be distinguished lithologically by the lack of granules, (2) is said to contain marine fossils, in contrast to the barren, presumably fresh-water beds beneath, and (3) grades eastward into dolomite which is entirely similar to the dolomite facies of the Eau Claire formation.

The sandstone termed "Mt. Simon" in eastern Minnesota directly underlies the Eau Claire *Cedaria* zone and in places contains much glauconite and glauconitic shale and siltstone (Atwater and Clement, 1935, pp. 1674-1676), which in Illinois is entirely confined to the Eau Claire formation. Most of this sandstone probably corresponds to the basal Eau Claire sandstone of north-

TABLE 1. TYPICAL HEAVY MINERAL ANALYSES IN PERCENTAGES

	Anatase	Apatite	Epidote	Garnet	Ilmenite	Leucoxene	Magnetite	Rutile	Titanite	Tourmaline	Zircon	Opaques	Unknown
Eau Claire sooty sandstone; base[1]	6	..	..	....	..	4	....	..	..	31	59	..	....
Mt. Simon light-colored facies; top[2]	1	..	..	....	1	3	....	..	..	27	68	..	....
Mt. Simon light-colored facies; lower[3]	1	..	..	Tr.	..	9	....	..	..	28	62	..	....
Mt. Simon light-colored facies; base[4]	..	..	..	9[a]	..	11	....	..	..	11	69	..	....
Mt. Simon light-colored facies; base[5]	..	..	..	20[a]	..	Tr.	40	..	..	20	20[b]	..	....
Mt. Simon red facies; upper[6]	..	..	..	....	5	1	....	..	..	19	76	..	....
Hinckley sandstone at Sandstone[7]	2	..	3[c]	....	..	18	Tr.[d]	2	..	12	63	..	Tr.
Hinckley sandstone at Net River[8]	1	..	1[c]	....	..	12	44[d]	1	..	13	27	..	Tr.
Fond du Lac sandstone[9]	..	50	..	7	..	A	....	..	..	23	13	4	2
Granite, Taylor No.1[10]	..	15	..	....	..	....	5	..	65	..	15[e]	..	....
Granite, McElroy No. 1[11]	..	C	R	....	C	P	P	P	..	..	C	..	....

[1]Well 7, 1710'-1720' (Herbert, 1944); [2]Charter member, Well 7, 1730'-1750' (Herbert, 1944); [3]Crane member, Well 7, 3790'-3805' (Herbert, 1944); [4]Crane member, Well 7, 3835'-3840' (Herbert, 1944); [5]Crane member, Well 5, 2900'-2905' (Marsden, 1933); [6]Gunn member, Well 5, 1645'-1650' (Herbert, 1944); [7]Tyler and others, 1940, p. 1512, sample P438B; [8]Tyler and others, 1940, p. 1512, sample P423B; [9]Tyler and others, 1940, p. 1508, sample P405; [10]Well 5, 2955'-2960' (Marsden, 1933); [11]Well 11, 3760'-3772' (Winchell, 1932; Grogan, 1949, pp. 98-99); [a]angular; [b]unzoned; [c]includes zoisite; [d]includes ilmenite; [e]zoned; A = abundant but not included in analysis; C = common; P = present; R = rare; Tr = trace.

ern Illinois, although true Mt. Simon strata locally may be included.

Except that it is indurated, the type Hinckley sandstone is exceedingly similar to the light-colored Mt. Simon sandstone of northern Illinois (Atwater and Clement, 1935, pp. 1669-1672, 1680; Stauffer and Thiel, 1941, pp. 15-23). The heavy mineral suites are fairly similar (table 1), although the Hinckley generally has higher proportions of magnetite, ilmenite and leucoxene and lower proportions of tourmaline and zircon. Feldspar is rare in the Hinckley, rare in the Mt. Simon of Illinois, except in the basal arkosic zone, and present only in very low percentages in the Mt. Simon of the type area (Stauffer and Thiel, 1941, p. 18, table 1).

The contact between the Hinckley and the underlying red Fond du Lac formation is gradational (Stauffer and Thiel, 1941, p. 17). The chief differences between the two sandstones are (1) the higher iron-oxide, shale, and feldspar content of the Fond du Lac, and (2) the presence of apatite and garnet and a higher percentage of leucoxene in the Fond du Lac heavy mineral suite. It seems most likely that the Fond du Lac is an arkosic, impure, basal facies of the Hinckley formation, the heavy minerals of which were derived from sources that later became buried. An analogous situation occurs in northern Illinois where the heavy mineral suite of basal Mt. Simon strata locally differs from that of the higher beds (table 1).

Raasch (1950) has presented evidence for the Cambrian age of the Hinckley and Fond du Lac formations. The writer tentatively correlates the entire Hinckley-Fond du

Lac sequence with the Mt. Simon sandstone of northern Illinois. Further study is needed to determine whether it has the same succession of conglomeratic and finer-grained members. Since no lithologic or physical evidence has been found for a formational break in the northern Illinois sequence, the name Mt. Simon is applied throughout.

The Mt. Simon sandstone of northern Illinois also is considered equivalent to the Bayfield and Jacobsville sandstones of the south shore of Lake Superior (Raasch, 1950) and to the Lamotte sandstone of eastern Missouri (Workman and Bell, 1948, pp. 2041-2043, figs. 2, 3).

Historical Interpretations

In Wisconsin the pre-Cambrian surface appears to have been a peneplain interrupted by monadnocks. The sparse data provided by wells in northern Illinois also suggest that the basement surface had slight relief.

It has been suggested that the Mt. Simon sandstone was rapidly deposited in a shallow, fresh- or brackish-water inland sea (Twenhofel, Raasch and Thwaites, 1935, pp. 1714-1715). The fact that the sandstone seems to be thickest in northern Illinois instead of thickening southward like most other Paleozoic formations supports this concept. Rapid sinking of the basement must have accompanied deposition to produce by far the thickest formation in Illinois. Periodic uplifts of the surrounding borderlands sent influxes of pebbly sand into the sea. Nonconglomeratic sand was laid down during intervals of crustal quiescence.

Probably the Mt. Simon quartz sand was derived mainly from weathered granites and gneisses to the north and was transported to the sea by streams. The general lack of rounding, frosting, and sorting indicates that the sand was not greatly reworked before deposition. The differences between the heavy mineral suites of the Mt. Simon and the underlying granite in northern Illinois (table 1) and the partial rounding of most Mt. Simon heavy minerals show that the bulk of the basal sand was not derived from the granite of that region. However, erosion of the granite contributed angular feldspar fragments to the initial sediments. The arkosic zone probably is thickest in the areas of greatest basement relief, as adjacent to monadnocks. That a minor part of the basement in northern Illinois or nearby areas consisted of schist is demonstrated by the presence of angular garnets in the heavy mineral suite of basal Mt. Simon strata in the Taylor and Wyman wells (5, 7) and by the occurrence of small schist fragments in the Mt. Simon of the Parish well (9).

In an area northward from Illinois a red clayey mantle probably developed on granitic rocks under conditions of low relief and a warm, humid climate, such as prevail at present in the southern Appalachian piedmont. It is believed that the Mt. Simon red facies was deposited off the mouth of a river which drained this area and discharged into the sea north of Belvidere, Boone County. The similarities in the heavy minerals of the red and light-colored facies suggest that both were derived from the same granitic terrane. Enlargement of the sea just prior to the marine invasion of Eau Claire time (Twenhofel, Raasch, and Thwaites, 1935, pp. 1714-1715) is reflected in abrupt overlap of the red sediments by a

relatively small thickness of white sandstone. Persistence of a drainage system which furnished red clastics is suggested by the recurrence of a similar red facies in the Franconia and uppermost Eau Claire strata of Boone County.

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PETROLOGY OF THE BASAL HIGH-PURITY BED OF THE BURLINGTON LIMESTONE*

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A high-purity, virtually chert-free limestone occurring near the base of the Burlington limestone in western Illinois is being mined or quarried at Quincy, Gladstone, and Pearl. This article presents the results of an initial study of the petrology of this 10 to 25-foot unit. Twenty thin sections, perpendicular to the bedding, were prepared from specimens collected at the localities mentioned, especially the Quincy area.

The specimens are mixtures, in varying proportions, of five principal components: (1) large fragments of crinoid plates and stem segments, which are inclusion-rich, unit-extinguishing sheets of calcite; (2) secondary white calcite, deposited in optical continuity upon the detrital fragments; (3) moderate to fine-grained fossil detritus, including fragments of bryozoa, pelecypods, brachiopods, and smaller bits of crinoid plates and stem segments; (4) very fine-grained dark gray interstitial calcite; and (5) small unit-extinguishing rhombs of dolomite. Coarsely crystalline specimens of the limestone consist chiefly of the secondarily enlarged pieces of crinoidal calcite. Finely crystalline varieties show pronounced banding in thin section, with different bands varying both in components and in particle size. The banding, in general, parallels the bedding planes of the rock, but in detail it may be contorted or lenticular at some places. Dolomite rhombs occur mostly in the fine-grained interstitial carbonate component, and are thus commonest in fine-grained varieties of the rock.

History of Events

The history suggested by the thin-section study is indicated in table I. In the first stage crinoid fragments were deposited with a mud containing abundant fossil fragments. The interstitial material between the crinoid fragments contains far too much debris and is too fine grained to have crystallized

FIG. 1.—Subparallel alignment of smaller detrital fragments. Parallel nicols, 20 X.

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from circulating water. A streakiness in the fine-grained portion of the interstitial material arises in part from the presence of elongate, laminated pieces of pelecypod shells, and, almost certainly, in part from the original deposition of elongate pieces of fossil detritus in planes essentially parallel with the ocean floor. However, a "streamline" effect seen in some places (fig. 1), in which sub-parallel particles diverge to go around larger particles, suggests local flowage during compaction which accentuated the other two features.

Secondary white calcite, free of inclusions, was deposited in optical

FIG. 2.—Portion of crinoid stem segment (a), secondary calcite rim (b), vein-like extension of rim (c), "island" (d), and fine-grained aggregate interpreted as result of late partial destruction of vein-like extension (e). Parallel nicols, 135 X.

continuity upon the large, inclusion-rich, unit-extinguishing sheets of calcite in crinoid plates. Less commonly (fig. 2) it forms vein-like extensions into fine-grained interstitial calcite. Secondary calcite from two or more nearby fragments commonly meets along a curving contact, giving rise to local areas in the rock that are coarsely crystalline aggregates (fig. 3). The deposition of secondary white calcite has been so extensive in some places as to cut across and isolate areas of streaked interstitial material. In these areas rearrangement of particles by flowage would have been unlikely without some disruption of the secondary calcite, which has not been seen;

FIG. 3.—Secondary calcite rims on adjacent grains grown together to form a coarse-grained rock, with small remnant areas of dark fine-grained interstitial calcite. Parallel nicols, 20 X.

hence deposition of secondary calcite is placed after compaction and flowage.

The margins of many of the secondarily enlarged calcite sheets in contact with interstitial carbonate are ragged, and the question arises as to which calcite is replacing the other. The fact that there are outlying islands of secondary white calcite in optical continuity with larger areas (fig. 2) suggests that the fine-grained interstitial calcite is the active replacing agent, but the "islands" may actually be continuous in the third dimension with the main mass. Further evidence is furnished by a few fine-grained aggregates of

FIG. 4.—"Ghost" composed of small grains in center of picture; two unit-extinguishing sheets of inclusion-rich crinoid calcite below. Crossed nicols, 65 X.

clear white calcite adjoining the secondary calcite projections, which are best explained as partially resorbed marginal portions of the projections.

"Ghosts" in the interstitial calcite show outlines of larger calcite particles that are now represented by an aggregate of small grains (fig. 4). Although the "ghosts" were not necessarily formed at the same time as the partial solution of the secondary carbonate rims, their presence does indicate that coarsely crystalline calcite has at one time during the history of the rock undergone alteration to a fine-grained aggregate. Both these solution effects can be placed, with considerable assurance, later than deposition of secondary calcite because cores of organic calcite lying within the secondary calcite rims are smooth and uncorroded.

The dolomite rhombs have been identified by Debye powder X-ray diagrams; in the absence of evidence to the contrary, they are assumed to be of a single age and of essentially constant composition. They are later than the postulated compaction, for they cut across "streamline" textures. They are earlier than at least part of the period of replacement of coarsely crystalline calcite, for many thin sections contain rhombs that have been partially dissolved (fig. 5). The prominence of this solution varies considerably within limited stratigraphic thicknesses. The age of the rhombs with regard to the deposition of secondary calcite is uncertain. A few rhombs project into the secondary calcite, but it is not yet known whether the rhombs have replaced the coarsely crystalline material, or the latter has replaced the material around the rhombs but left them untouched.

MINOR COMPONENTS

Uncommon small irregular areas of low birefringence, moderate index, and non-uniform extinction are found within large unit-extinguishing crinoid plates (fig. 6). They are not potash feldspar, since a sodium cobaltinitrite staining test gave neg-

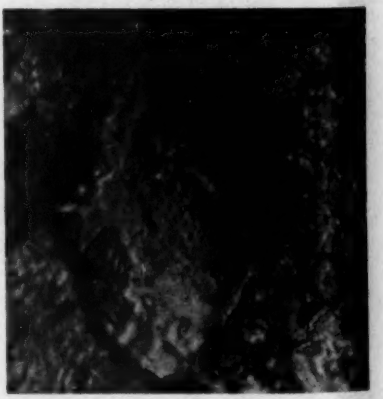

FIG. 5.—Dolomite rhomb partially dissolved along left-hand margin. Parallel nicols, 280 X.

Table I. History of Events

	1. Deposition of detritus from crinoids; interstices between larger crinoid fragments filled with mixture of lime mud, glauconite granules, and fossil detritus.	
	2. Compaction locally accentuates parallelism of elongate particles in interstitial material.	
	3. Deposition of secondary calcite in optical continuity upon crinoid fragments	Formation of dolomite rhombs.
Some crinoid fragments in interstices reduced to fine-grained aggregates.	4. Secondary calcite partially replaced by fine-grained aggregate, perhaps contemporaneously with solution of dolomite rhombs and with replacement of small detrital fragments.	Partial solution of dolomite rhombs.

FIG. 6.—Aggregate of grains which may be secondary silica, lower center near margin of crinoid stem segment. Crossed nicols, 65 X.

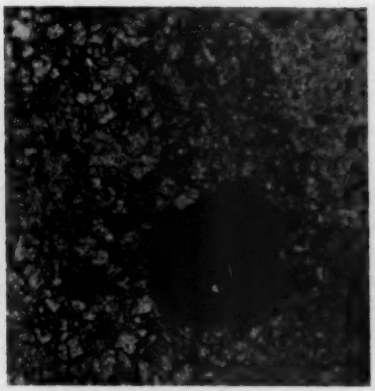

FIG. 7.—Glauconite grain in dolomite-rich Burlington limestone. Parallel nicols, 65 X.

ative results, but they may be secondary silica.

Rounded areas of a greenish material (fig. 7) give an X-ray pattern and a differential thermal curve which correspond in general with those expectable for glauconite, but this identification will not be meaningful until glauconite and related layer-lattice minerals have undergone much more study as mineral types. A basal spacing of 10 Ångström units was noted, but other critical X-ray reflections were obscured by lines of quartz, which occurred even in the 1-micron fraction of the "glauconite." These rounded greenish areas do not cut across other structures, and are most likely detrital in origin. Many dolomite crystals end abruptly against the "glauconite," without completing the rhomb shape. In some cases they penetrate into cracks, but no actual replacement of "glauconite" by either calcite or dolomite has been noted.

METAMORPHIC DEVELOPMENT OF THE EASTERN PART OF THE CRAWFORD NOTCH QUADRANGLE, NEW HAMPSHIRE

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The Crawford Notch quadrangle is situated in the White Mountains of central New Hampshire. The rocks in the quadrangle are of two major types: (1) metamorphic and plutonic rocks of Devonian age and (2) mildly alkaline igneous rocks of probable Mississippian age. This paper is concerned with the evolution of the Devonian metamorphic and plutonic rocks.

Lithology

Terminology.—The term "granitic" material is used in a megascopic descriptive sense to refer to light-colored granitic-looking rock contained in gneiss and schist. The terms granite, quartz monzonite, granodiorite, and quartz diorite are used purely in a descriptive sense to designate essentially massive granular rocks which have mineralogic compositions according to the classification of Johannsen (1939). None of these terms have genetic connotations.

General features.—The Devonian rocks consist mainly of gneiss and schist of the Littleton formation which contain about 50 percent of intermixed "granitic" material. A small amount of fine-grained gneiss and lime-silicate granulite is locally interbedded in the gneiss and schist. Also in the area are three bodies of quartz monzonite each approximately two miles across.

Littleton formation.—The bulk of the Littleton formation consists of medium-grained biotite-muscovite gneiss which contains approximately an equal amount of "granitic" material in lenses, bands, and small irregular bodies. Locally, the amount of "granitic" material ranges from a few percent to almost 90 percent. It is predominantly concordant in rocks which contain less than 50 percent. Much is discordant in rocks which contain more than 50 percent. The mineralogic composition of the average gneiss is given in column 1 of table 1. The mineralogic composition of the "granitic" material is like that of column 3 of table 1.

Six areas of schist which range from approximately one-half to two square miles occur in the gneiss in the northeastern quarter of the quadrangle. The typical schist is medium-grained muscovite-biotite-chlorite schist and is spangled with porphyryblasts of muscovite approximately 0.5 to 1 cm. across. Most of the schist contains approximately 50 percent "granitic" material similar to that in the gneiss. In many areas the schist occurs as fragments ranging from an inch to many feet across. A body of schist in the northeast corner of the quadrangle and a small projection of schist from a large area in the Mt. Washington quadrangle to the north are the only large areas of schist which contain

TABLE 1.—APPROXIMATE MODES OF METAMORPHIC AND PLUTONIC ROCKS, CRAWFORD NOTCH QUADRANGLE, N. H.

	1	2	3	4	5	6	7	8
Biotite	20	10	..	30	..	..	30	3
Muscovite	20	40	20	20	..	..	..	2
Quartz	35	15	50	20	..	25	30	30
Plagioclase	20	15	25	20	30	25	20	33
Perthite	..	..	5	..	..	..	..	30
Chlorite	5	20	..	10	..	..	..	2
Sillimanite	tr	tr	..	..	..	..	..	tr
"Orthoclase"	..	..	..	..	40	30	..	..
Actinolite	..	..	..	..	20	..	10	..
Diopside	..	..	..	..	10	20	..	..
Garnet	..	..	..	..	..	..	10	..
Percent of anorthite in plagioclase	20	20	20	20	50	60	80	20

1. Average mode of gneiss.
2. Average mode of schist.
3. Average mode of "granitic" material in schist.
4. Fine-grained thin-bedded gneiss, railroad cut, Crawford Notch.
5. Actinolite-diopside granulite, central part of Crawford Notch quadrangle.
6. Diopside-actionolite granulite, central part of Crawford Notch quadrangle.
7. Biotite-actinolite-garnet granulite, east edge of Crawford Notch quadrangle.
8. Average mode of quartz monzonite.

practically no "granitic" material. An average mode of the schist is given in column 2 of table 1. An average mode of "granitic" material in schist is given in column 3 in table 1.

Lenses and groups of beds of fine-grained gneiss and lime-silicate granulite which range from a few inches to tens of feet thick are scattered through the gneiss and schist. The bedding is almost undeformed in most places, and in many places resembles the bedding of varved clay. The composition differs greatly in different beds. Some of the most typical compositions are shown in columns 4 to 7 in table 1. Much of the fine-grained gneiss and lime-silicate granulite occurs in broken fragments and slabs, ranging from a few inches to tens of feet across, in gneiss and schist containing 50 percent "granitic" material.

Quartz monzonite.—Rocks included under the term quartz monzonite actually range in composition from sodic quartz diorite to granite. The structure ranges from gneissose to massive. The average rock is slightly foliated biotite-muscovite quartz monzonite. An average mode is given in column 8 of table 1.

Much of the quartz monzonite occurs in dikes and irregular small bodies in the Littleton formation. It is similar in appearance to the predominantly concordant "granitic" material in the Littleton formation. The distinction between the quartz monzonite and the "granitic" material is arbitrary and is based chiefly on structural relations. The quartz monzonite is predominantly discordant and occurs in larger bodies than the "granitic" material.

The quartz monzonite occurs in only three bodies large enough to map geologically. The contacts are gradational into the gneiss and schist of the Littleton formation. An interesting relationship exists between the size and composition of the bodies of quartz monzonite. In general, the small bodies are quartz dioritic or granodioritic in composition, whereas the larger bodies approach a true granitic composition.

STRUCTURE

Only a brief and generalized account will be given of the structural features. The rocks are greatly and irregularly contorted and the detailed structural relations are not easily discernable because of their

TABLE 2.—CHEMICAL ANALYSES OF DEVONIAN METAMORPHIC AND PLUTONIC ROCKS IN NEW HAMPSHIRE

	1	2	3	4	5	6	7	8
SiO_2	58.92	58.14	61.40	56.23	66.68	62.87	63.5	68.8
TiO_2	0.93	0.65	0.92	1.11	0.87	0.92	0.9	0.4
Al_2O_3	18.55	21.00	19.04	23.15	18.17	17.43	17.6	15.9
Fe_2O_3	0.94	0.33	0.63	1.17	0.90	0.55	0.9	0.5
FeO	6.63	6.32	6.90	6.94	4.98	6.67	6.5	4.0
MnO	0.08	0.06	0.07	0.12	Tr.	0.23	Tr.	Tr.
MgO	3.24	3.41	2.10	2.21	1.42	2.71	2.5	1.2
CaO	0.48	0.32	0.90	0.26	0.76	0.59	0.7	1.5
Na_2O	1.49	1.10	1.30	1.14	0.74	1.71	1.7	2.9
K_2O	3.74	3.85	3.74	4.53	2.89	4.08	4.0	4.2
H_2O+	3.90	4.47	2.89	2.75	1.75	2.10	2.0	0.6
H_2O-	0.11	n.d.	0.06	0.09	0.40	0.08		
CO_2	0.25	0.00	0.01	0.01	0.00	0.02		
P_2O_5	0.14	0.00	0.08	0.18	Tr.	0.11		
S	0.17	0.09	0.08	0.02	0.05	0.04		
ZrO_2	n.d.	0.04	n.d.	n.d.	n.d.	n.d.		
C	n.d.	n.d.	n.d.	n.d.	0.29	n.d.		
O–S corr.	–0.06	.....	–0.03	.....	.....	–0.02		
Total	99.51	99.78	100.09	99.90	99.90	100.09	100.0	100.0

1. Slate, Littleton formation, Littleton quadrangle (Billings, 1941, p. 902).
2. Slate, Littleton formation, Littleton quadrangle (Billings, 1937, p. 556).
3. Fine-grained pseudo-andalusite schist, Littleton formation, high-grade zone, Mt. Washington quadrangle (Billings, 1941, p. 902).
4. Coarse pseudo-andalusite schist, Littleton formation, high-grade zone, Mt. Washington quadrangle (Billings, 1941, p. 902).
5. Sillimanite schist, Littleton formation, high-grade zone, Franconia quadrangle (Billings, 1938).
6. Banded gneiss, composed of approximately equal amounts of dark and light bands, Littleton formation, Mt. Washington quadrangle (Billings, 1941, p. 902).
7. Approximate average composition of gneiss and schist in the Littleton formation, Crawford Notch quadrangle. Calculated from the average mode.
8. Approximate average composition of quartz monzonite in the Crawford Notch quadrangle. Calculated from the average mode.

complexity and irregularity, the intense metamorphism, and the lack of outcrops in many critical places. Most of the major folds probably trend approximately northeast-southwest. Minor folds rarely show systematic relations to one another or to major folds. Irregular minor folds are particularly conspicuous in areas of gneiss and schist which contain abundant "granitic" material.

Much of the quartz monzonite occurs in irregular discordant bodies which are less than 50 feet across. It is so abundant in most of the gneiss and schist that it cuts these highly contorted rocks into extremely coarse breccias with blocks ranging from an inch to several hundred feet across.

The large bodies of quartz monzonite are irregularly shaped, essentially cross-cutting and gradational into the surrounding gneiss and schist. The foliation of the quartz monzonite and the foliation of the abundant bands of gneiss and schist within the quartz monzonite are essentially parallel to that of the surrounding gneiss and schist.

METAMORPHISM

Original nature of the Littleton formation.—Local preservation of sedimentary bedding, the chemical composition, and correlation with rocks of unmistakable sedimentary origin in the Littleton-Moosilauke area indicate that the gneiss, schist,

fine-grained gneiss and lime-silicate granulite originally were sediments. Lithologic correlation and comparison of the chemical composition of the high-grade metamorphic rocks in the Crawford Notch area with those of the low-grade shales and slates in the Littleton quadrangle indicate that the original sediments in the Crawford Notch region were predominantly shales and sandy shales. Analyses and calculated analyses of such rocks may be compared in table 2. The mineralogic compositions of the fine-grained gneiss and lime-silicate granulite (table 1) indicate that small amounts of impure sandstone, arkose, and dolomite were interbedded with the shale.

Stage of recrystallization. — The first major change during metamorphism of the shaly sediments probably was simple recrystallization with essentially no differential movement of chemical constituents over distances greater than a few millimeters. The resulting products were schist and gneiss which probably contained no intermixed "granitic" material. Although most of the recrystallized rocks were subsequently greatly modified, local remnants have survived. The rocks were recrystallized in response to increase in temperature and pressure, particularly differential pressure. The generally coarse grain-size and the widespread occurrence of sillimanite indicate that high-grade conditions were reached throughout most of the quadrangle.

Stage of reconstitution.—Throughout most of the quadrangle simple recrystallization was followed by a stage of reconstitution which involved widespread movement of material. The resulting product was gneiss and schist containing abundant intermixed "granitic" material. Movement of material is clearly indicated by the occurrence of all stages of destruction of the original sedimentary features which survived the stage of recrystallization. Furthermore, all steps in the regrouping of constituents into light and dark bands can be observed. Although movement of material was widespread the similarity in composition (table 2) of the reconstituted rocks and the original and recrystallized rocks indicates that the distance of movement of the individual constituents probably was less than a few feet or tens of feet.

The reconstitution of the schist and gneiss into rocks with segregated dark and light bands is believed to have taken place by a process of metamorphic differentiation essentially like that proposed by Eskola (1932). The process depends chiefly upon the greater solubility of the light-colored minerals and a tendency for the constituents of such minerals to collect and crystallize along the foliation. Metamorphic differentiation was favored by continuation and increase in temperature conditions from the preceding stage of recrystallization. The movement of constituents in metamorphic differentiation probably was chiefly in solution by flow and diffusion through inter-granular and larger spaces. Solid diffusion through crystal structures probably was not important because the larger atoms or ions such as K, Na, and Ca apparently moved as easily as the smaller Fe, Mg, and Al atoms.

Stage of metasomatism.—A stage involving differential movement of material followed the stage of reconstitution and resulted in the formation of the typically discordant quartz monzonite. The stages prob-

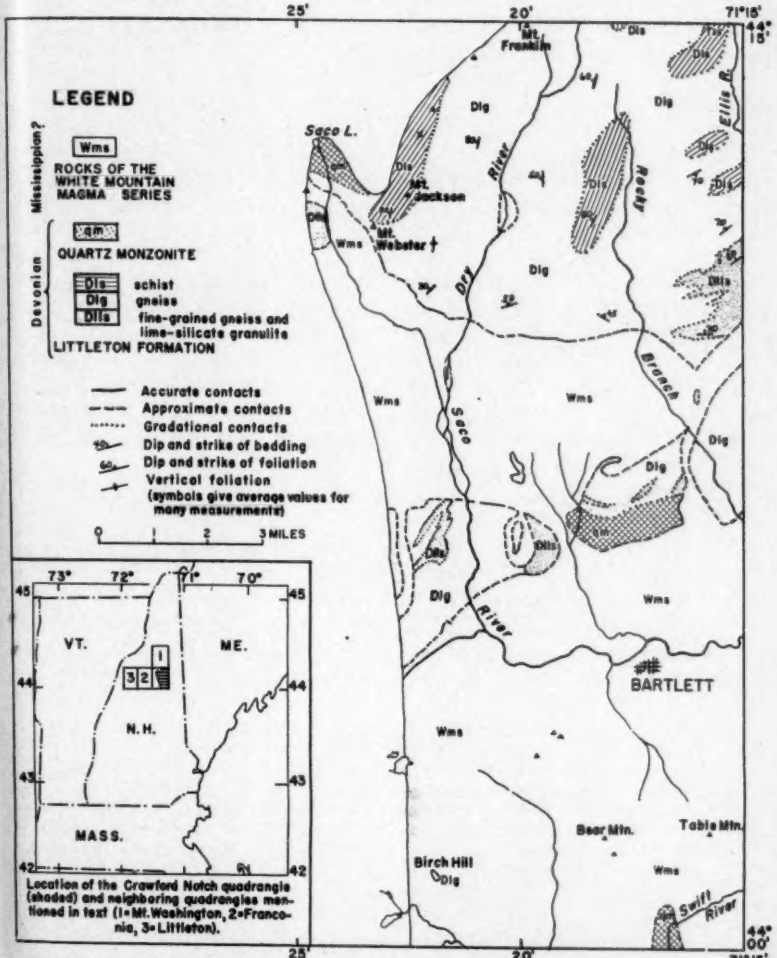

PLATE I. GEOLOGIC MAP OF THE EASTERN PART OF THE CRAWFORD NOTCH QUADRANGLE, N.H.

ably were transitional because complete gradation exists between the composition and structural occurrence of the "granitic" material in gneiss and schist and those of the quartz monzonite.

Comparison of the composition of the average quartz monzonite with that of the older rocks (table 2) indicates an introduction of CaO, Na_2O, K_2O, and SiO_2 and a removal of FeO, MgO, and Al_2O_3. The differential movement of material causing the changes in composition probably was aided by widespread fracturing of the previously formed rocks which allowed easier movement of material over distances of many feet. The formation of the large bodies of quartz monzonite may have been favored by localized extreme fracturing. Intermediate steps in the formation of the larger bodies are apparent in many places.

Metasomatism or intrusion of melts appear to be the major alternative mechanisms for the production of the quartz monzonite. Metasomatism by solutions contributing CaO, Na_2O, K_2O and SiO_2 and removing FeO, MgO, and Al_2O_3 is believed to be the most probable mechanism because of abundant evidence of replacement and because of the large amount of heat necessary to produce a silicate melt.

Retrograde stage.—The preceding stages produced under conditions of increasing temperature and pressure were followed in many places by changes apparently in response to conditions of decreasing intensity. The changes were similar to those in many other areas. The most conspicuous were chloritization of biotite and sericitization of sillimanite, andalusite, and plagioclase.

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PREGLACIAL GRAVELS IN HENRY COUNTY, ILLINOIS

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Preglacial deposits of iron-stained chert gravels underlie the glacial drift at a number of localities in the Mississippi Valley region (fig. 1). These gravels, which generally have been referred to the late Tertiary Lafayette formation, are significant in recording geologic events during closing stages of the lost interval between Pennsylvanian bedrock deposition and Pleistocene glaciation. It is the purpose of the present paper to describe gravels from a new locality in western Illinois and to indicate their bearing on late Tertiary geomorphic events.

Description

The gravels are exposed in a highway cut (fig. 2) 7 miles northwest of Kewanee, Henry County, Illinois (400 feet N. of S. W. cor. sec. 3, T. 15 N., R. 4 E.), in the section described below.

	Thickness		Depth	
	Ft.	In.	Ft.	In.
Wisconsin drift				
Peorian loess				
Soil, gray	0	6	0	6
Loess, tan, mottled gray, non-calcareous	3	0	3	6
Loess, tan to gray, calcareous, concretions	2	0	5	6
Farmdale loess				
Silt, carbonaceous, peaty, gray with black humus streaks, abundant gastropods in pockets, non-calcareous	0	4	5	10
Loess, maroon-brown, compact, non-calcareous, gastropods	2	0	7	10
Illinoian drift				
Gumbotil, gray-brown, siliceous residuals, non-calcareous except for some secondary enrichment at top	2	6	10	4
Till, yellow-brown, abundant chert mixed with other rock types, non-calcareous	1	0	11	4
Sand, brown, in local channel	1	0	12	4
Tertiary gravel				
Gravel, 80% brown fossiliferous chert, iron oxide patination, rounded to angular, average 1 to 2 inches, irregular basal contact	3	0	15	4
Pennsylvanian (Canton) shale				
Shale, yellow-buff, micaceous, clayey, broken down by weathering	3	6	18	10
Shale, buff-gray, stratified	5	0	23	10

The Tertiary gravels differ from all known glacial deposits in the area in their degree of surface alteration, polish, and uniform siliceous composition. Their lithology, based on a count of 120 pebbles, is 79% chert, 18% vein quartz, and 3% quartzite. Crystalline rocks and local bedrock appear to be completely absent. Nearly all the cherts have a yellow-brown iron oxide patina 1-3 mm. thick which is as hard and dense as the interior of the pebbles. A few cherts have a whitish surface alteration and the quartz and quartzite pebbles show surficial iron-staining.

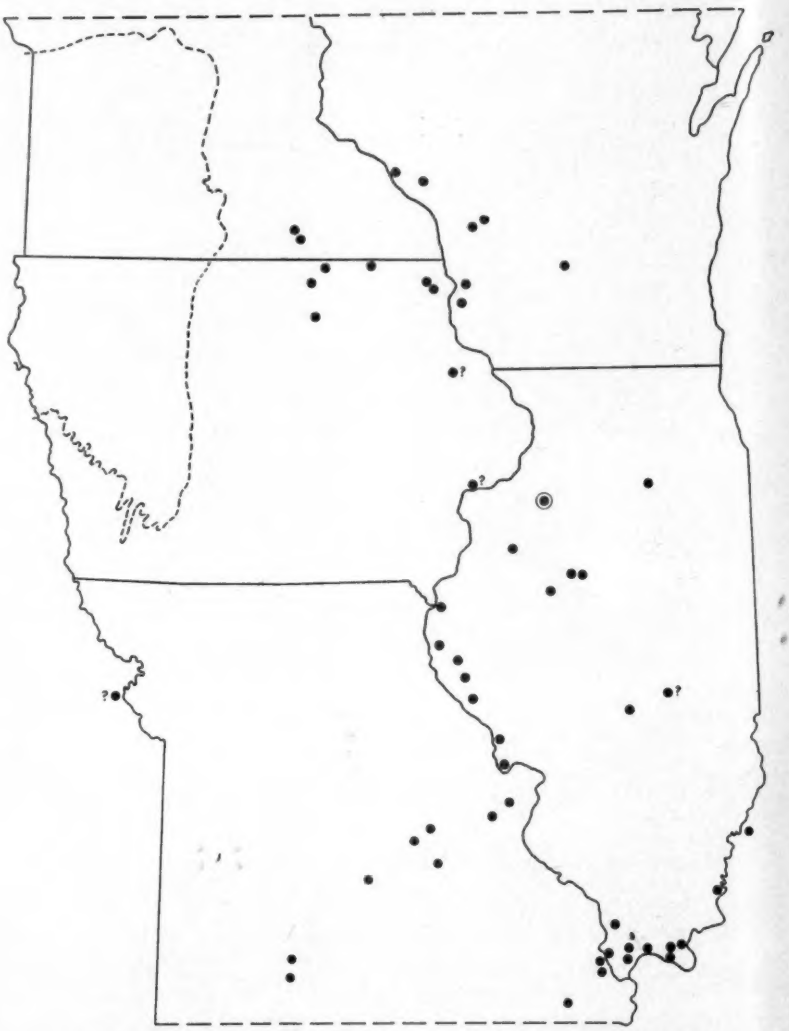

FIG. 1.—Occurrences of preglacial Lafayette-type gravels in the Mississippi Valley region. The Henry County locality is circled. The eastern boundary of Cretaceous deposits in Iowa and Minnesota is shown by a dashed line. Based on references cited and field notes on south-central Missouri by J H. Bretz.

The brown chert pebbles, which make up 70% of the deposit, contain fossil corals, crinoids, and brachiopods of Lower and Middle Silurian age (Heinz Lowenstam, personal communication, 1950).

The pebbles range in diameter from a fraction of an inch to 7 inches, the average being between 1 and 2 inches. The brown chert pebbles are larger than the other types and there is a distinct variation in average size from one part of the exposure to another. All the cherts are angular. Many pebbles are broken rounds, some are chipped, and a few have percussion markings. The gravels are unconsolidated, and the matrix, if it was ever present, has been removed by weathering.

The basal contact of the gravel is irregular and slopes to the south and west. Since the low ridge crest on which the gravels occur slopes northeast, it is clear that the gravels were laid down on a land surface unrelated to the present topography.

The upper part of the Canton shale underlying the gravels is oxidized and mechanically weathered to a depth of about 3 feet. Under the microscope the weathered shale is seen to differ from the unaltered shale in its lack of stratification, disaggregation into silt and clay-size particles, oxidation, and content of limonitic aggregates.

The gravels occur at an elevation of 730 feet near the northern margin of a buried bedrock upland, which locally has an average elevation of about 750 feet and lies 450 feet above the buried bedrock valley of the ancient Mississippi river some 15 miles to the north. The upland surface has been correlated with the Lancaster peneplain of the Driftless Area (fig. 1) (Horberg, 1946, pp. 186-188.) Farther south in western and southern Illinois nearly all occurrences of preglacial gravel are on this surface or equivalent surfaces correlated with the Ozark and Calhoun peneplains.

Correlation and Age

Although it is probable that similar deposits of different ages are represented and that some gravels are reworked, the deposits in the Mississippi Valley region can be correlated in a general way by lithology and physiographic position. On this basis the gravels in Henry County appear to be equivalent with the Windrow formation of Wisconsin, Iowa, and Minnesota (Thwaites and Twenhofel, 1921); the "Tertiary" gravels of LaSalle County (Willman, 1942, pp. 140-141), Peoria County (Udden, 1912, p. 50) and other counties in western Illinois (Worthen, 1866, p. 330; 1870, p. 37; Bannister, 1870, p. 179; Salisbury, 1891, pp. 252-253); the Grover gravel of the St. Louis region (Salisbury, 1892, pp. 183-186; Rubey, 1931); and the Lafayette gravel of southern Illinois and southeastern Missouri (Lamar and Sutton, 1930, pp. 857-859). Correlation with the Rockville conglomerate at Dyersville, Iowa (McGee, 1891, p. 304) and the Pine Creek conglomerate near Muscatine, Iowa (Udden, 1899) is questionable because of the high proportion of crystalline rocks in these deposits. Also it is uncertain whether the two occurrences at lower elevations within the area of the Central Illinois peneplain (fig. 1) are primary or reworked.

A Tertiary age for the gravels farther south is evidenced by their presence on truncated Eocene formations at the head of the Gulf em-

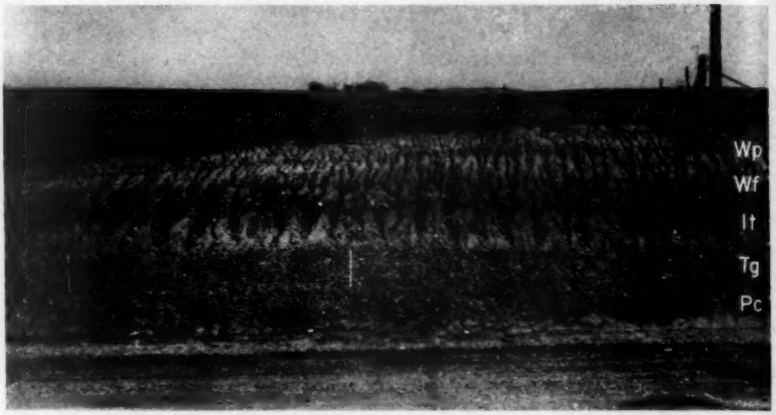

FIG. 2.—Highway cut 7 miles northwest of Kewanee, Illinois. Wp—Peorian loess; Wf—Farmdale loess; It—Illinoian gumbotil and till; Tg—Tertiary gravel; Pc—Pennsylvanian (Canton) shale.

bayment and by the occurrence of Tertiary wood in the gravels near Grover, St. Louis County, Missouri (Rubey, 1931). Because the Eocene formations were beveled by the Ozark peneplain before deposition of the gravels, a late Tertiary age is indicated. A similar age for the gravels in western Illinois is evidenced by their occurrence on a buried bedrock surface which appears to be the northward continuation of the Ozark peneplain (Horberg, 1946, pp. 186-188).

INTERPRETATION

The gravels in Henry County probably were derived largely from residual accumulations on Silurian formations, which occur less than 20 miles to the north, and were deposited, along with pre-Cambrian materials from farther north, by a south-flowing stream. This is evidenced by the composition of the gravels and their angularity and poor sorting. The absence of locally-derived Pennsylvanian rocks in the gravels further suggests that they represent a widespread aggradational deposit rather than a channel fill and also that they are primary rather than locally re-worked from older gravels.

The physiographic position and character of the gravel in Henry County are in full accord with other occurrences in the Mississippi Valley region and suggest that the following major geomorphic events were contemporaneous over a wide area:

1. Development of the Lancaster-Calhoun-Ozark peneplain in middle to late Tertiary time. Weathering of the Canton shale in Henry County.

2. Uplift of gravel-source areas to the north and initiation of a new cycle marked by gravel deposition. Removal of the upper part of the weathered zone on the Canton shale and deposition of gravel in the local area by a south-flowing stream.

3. Development of the Central Illinois peneplain and Havana strath in central Illinois (Horberg, 1946). Weathering of gravels and

probably some subsequent erosion and redeposition in western Illinois.

4. Erosion of deep bedrock valleys and removal of gravels except for patches on remnants of the Lancaster surface.

5. Pleistocene glaciation resulting in further stripping of gravels and their final burial. Henry County probably was glaciated during the Nebraskan and Kansan stages, as well as the Illinoian, although the record at the gravel locality is incomplete.

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THE NEDA FORMATION IN NORTHEASTERN ILLINOIS[1]

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In the vicinity of Mayville, Wisconsin, an "oolitic hematite" called "seed ore," "flaxseed ore," or "shot ore," was originally designated by Chamberlin[3] as the "Clinton iron ore deposit." He described the grains of iron ore as "little lens-shaped concretions" composed of hydrated hematite averaging 1/25 inch (1 mm.) in diameter, but varying from 1/10 inch (2.5 mm.) to those that are very minute. Cross sections indicated that the ore occurs between the Cincinnati shale and the "Niagara limestone." He stated that, although a few fossils of Cincinnatian age were reported to have been found in ore enclosed in a mass of glacial drift, an obvious unconformity at its base in outcrop and a less apparent break at the top indicate the deposit to be Silurian. He suggested that it was made in detached shallow basins over which the succeeding Silurian sea spread more widely. Figure 1 is a photograph of ore recently obtained at Mayville.

Thwaites[4] further described the deposits of "Clinton" ore as occurring in eastern Wisconsin in broad lenses varying in thickness up to a known maximum of 55 feet. He pointed out that at many places where the iron ore is not present there are nevertheless beds of red rock at the same horizon, and presented a map (fig. 2) showing the known occurrences of iron ore and red rock. He reported also that in the Green Bay region the ore is interbedded with shale, and in an area

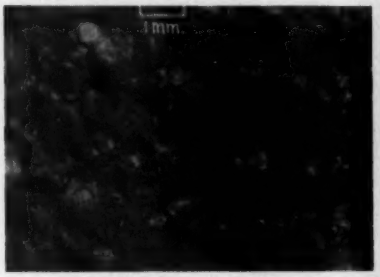

FIG. 1.—Neda Iron Ore from Mayville, Wisconsin (X6).

about 15 miles southeast of Mayville it appears from well cuttings to be broken up and mixed, or perhaps interstratified, with limestone.

Savage and Ross[5] pointed out that the relations of the iron ore to formations both above and below are unconformable, but that fossils collected from the ore in place indicate it to be of Maquoketa (Cincinnatian) age. They described the deposit as containing pebbles of shale, iron ore, and iron-oxide-replaced fossil fragments and suggested that the deposit is a formation laid down in local basins that, because of the presence of marine fossils, probably were connected and remained after the main portion of the normal marine Maquoketa sea had withdrawn from the greater part of the region

[1] Published by permission of the Chief, Illinois State Geological Survey. (Presented at the 1949 meeting of the Academy.)

[2] Geologist and Head, Subsurface Geology Division.

[3] Chamberlin, T. C., Geology of Wisconsin, Wisconsin Geol. Sur., vol. 2, 1878, pp. 327-335.

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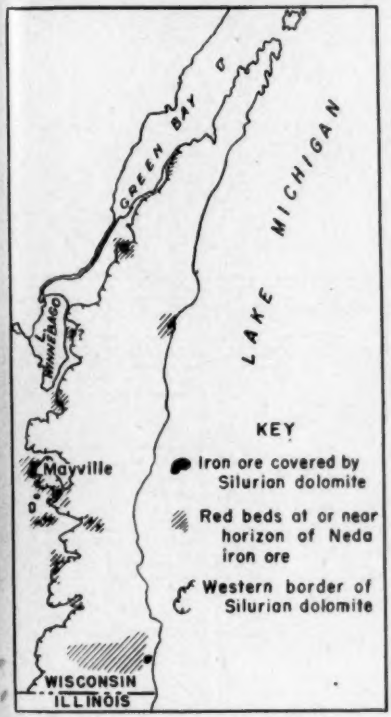

FIG. 2.—Locations of Neda Iron Ore in Wisconsin (after Thwaites).

farther south in the Mississippi valley. They named it the "Neda Iron Ore" formation.

Hawley and Beavan[6] made a detailed analysis of the minerals of the Neda Iron Ore formation. They determined that nuclei observed in the oolites consist of: (a) fragments of reworked ore, (b) fossil fragments, (c) mineral or rock fragments, and (d) cross-shaped objects. They emphasized, however, that most of the oolites show no central nuclei. They showed that the spheroids are composed of at least 26 varieties of minerals, chief of which are goethite (Fe_2O_3,H_2O), calcite, and halloysite ($Al_2O_3.2SiO_2.nH_2O$). Halloysite is a clay that was found to compose most of the insoluble residue after treatment with acid and that looked under the binocular microscope like finely granular unglazed porcelain, making up the fragile spheroidal shells of the spheroids. There are ten varieties of phosphates, and 50% of all phosphorus is contained in the outer shells of the spheroids. The non-oolitic portion of the ore is largely pore space. Crystalline hematite has grown from the spheroids into part of the space, and there are a number of sedimentary minerals such as quartz and materials from the weathering of igneous rock. The most abundant transported material consists of angular grains of scoriaceous lava largely altered to iron oxide. There are rounded fragments of reworked ore and nodules of calcite and dolomite. The authors state that the source of the predominant ore minerals is a baffling problem.

The Neda iron-bearing formation is reported in the same stratigraphic position in eastern Iowa[7], eastern Kansas[8], and northwestern Missouri[9].

Athy[10] very fully described the Neda deposit in Illinois but called it the Noix Oolite of basal Alexandrian (Silurian) age. The outcrops which he described, situated in sections 26, 27, and 35, T.32 N., R.10 E., Kankakee County, are the only ones known in Illinois. He reports the iron ore spheroids as occurring in a

[6] Hawley, J. E., and Beavan, A. P., Mineralogy and genesis of the Mayville iron ore of Wisconsin, Amer. Mineralogist, vol. 19, 1934, pp. 493-514.

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[10] Athy, L. F., Geology and mineral resources of the Hersher quadrangle, Ill. Geol. Sur. Bull. 55, 1928, pp. 33-38.

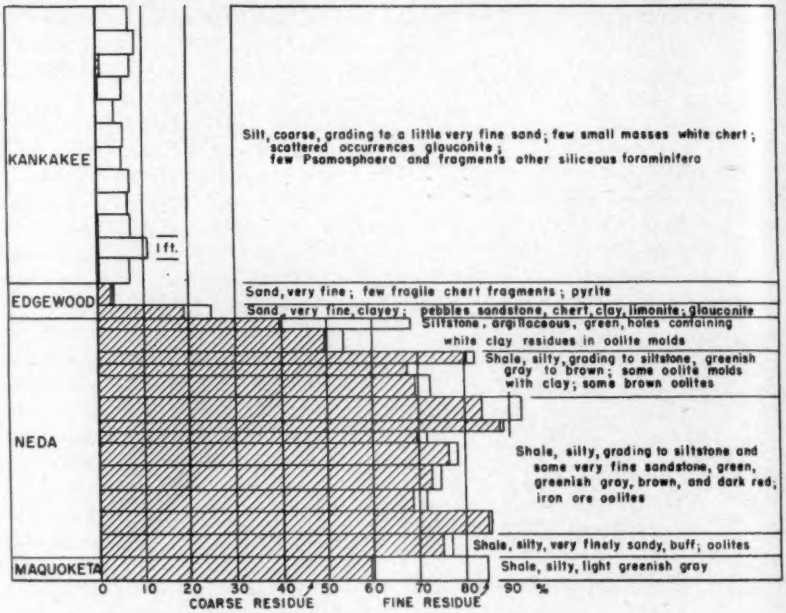
KANKAKEE
EDGEWOOD
NEDA
MAQUOKETA
1 ft.
Silt, coarse, grading to a little very fine sand; few small masses white chert; scattered occurrences glauconite; few Psamosphaera and fragments other siliceous foraminifera
Sand, very fine; few fragile chert fragments; pyrite
Sand, very fine, clayey; pebbles sandstone, chert, clay, limonite; glauconite
Siltstone, argillaceous, green, holes containing white clay residues in oolite molds
Shale, silty, grading to siltstone, greenish gray to brown; some oolite molds with clay; some brown oolites
Shale, silty, grading to siltstone and some very fine sandstone, green, greenish gray, brown, and dark red; iron ore oolites
Shale, silty, very finely sandy, buff; oolites
Shale, silty, light greenish gray
0 10 20 30 40 50 60 70 80 90 %
COARSE RESIDUE
FINE RESIDUE

FIG. 3.—Graph of insoluble residues from Neda formation and associated strata in outcrop above spring in NW. ¼ SE. ¼ NE. ¼ sec. 27, T. 32 N., R. 10 E., Kankakee County, Illinois.

matrix of reddish brown, purplish, and green ferruginous shales and shaly dolomite reaching a thickness of 8 feet, 2 inches, and resting unconformably on olive-green Richmond (Maquoketa) shale. The spheroids are generally the size of fine to coarse sand averaging .5 mm. across. The shale was reported to contain much silt and fine quartz sand (up to .25 mm. diam.) and some medium sand (.25 to .50 mm.).

The writer obtained insoluble residues from samples, taken at one-foot intervals or less from several of the outcrops along Kankakee River, by treating the rock samples with weak hydrochloric acid. The graph of the most complete section (fig. 3), taken at the locality figured by Athy on page 32 and described on page 33 (see footnote 10), shows 10½ feet of Neda ore-bearing material on top of the Maquoketa shale and under the Edgewood formation. The insoluble material of the Neda deposit consists of: (a) silty shales to siltstones variously colored brown, yellow, greenish, and purplish by iron oxide cement; (b) some very fine sand that grades in the middle of the deposit to very fine sandstone; (c) iron-ore spheroids scattered in variable proportions but nowhere composing most of the deposit as in Wisconsin. The total residue varies from 54 to 93 percent. These proportions are not essentially different from the proportions in the Maquoketa shale below, which in the single sample taken amounted to 85 percent. Neither is the silty shale to siltstone matrix greatly different, except for some sand content, from the

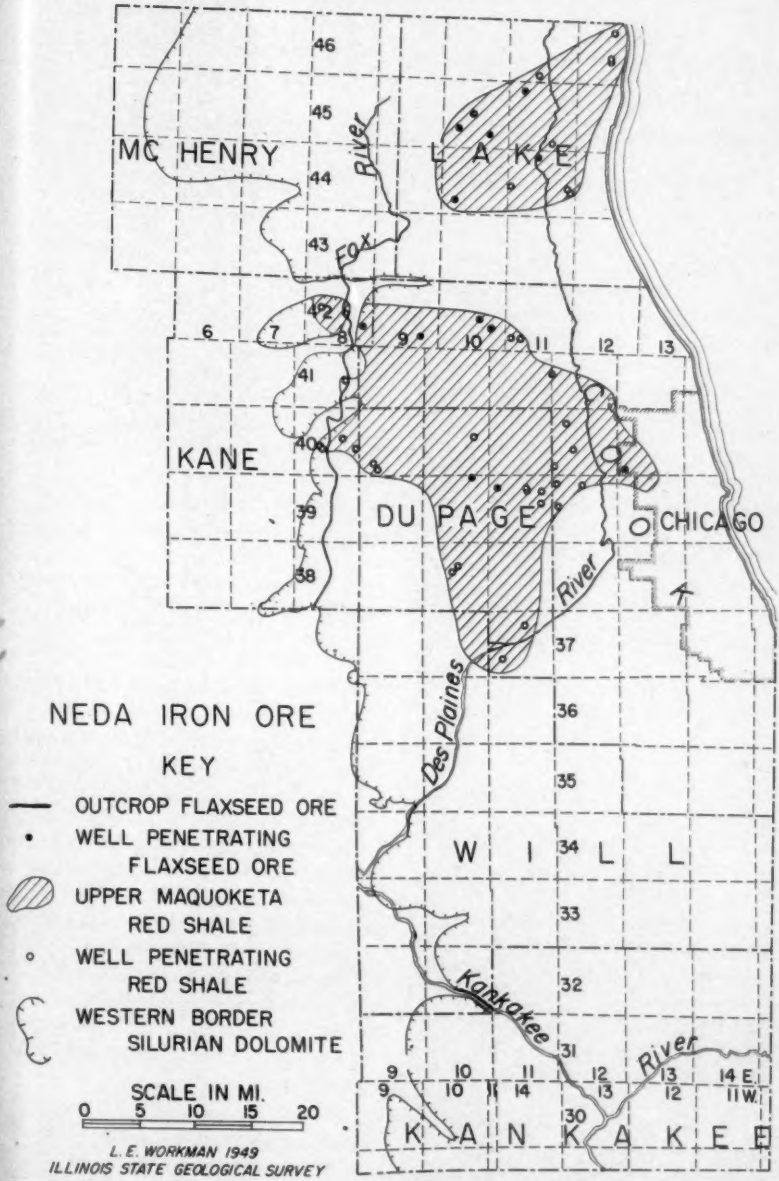
MC HENRY
LAKE
KANE
DU PAGE
COOK
CHICAGO
WILL
KANKAKEE
Fox River
Des Plaines River
Kankakee River
NEDA IRON ORE
KEY
OUTCROP FLAXSEED ORE
WELL PENETRATING FLAXSEED ORE
UPPER MAQUOKETA RED SHALE
WELL PENETRATING RED SHALE
WESTERN BORDER SILURIAN DOLOMITE
SCALE IN MI.
0 5 10 15 20
L. E. WORKMAN 1949
ILLINOIS STATE GEOLOGICAL SURVEY

FIG. 4.

Maquoketa silty shale. On the other hand, the residue proportions are quite different from the 25 percent residue of the overlying Edgewood and there is an abrupt change from the silty sandy shale below to a sandy conglomeratic dolomite above. The pebbles of the conglomerate consist of grains of underlying shale and a few weathered iron ore spheroids. Were it not for the pebbles the proportion of insoluble residue of the lowest sample of Edgewood would be similar to that of the next sample above, that is, less than 10 percent.

In the subsurface of the Chicago region (fig. 4) the spheroids of iron ore are found in a variety of sediments. Like those along Kankakee River, they occur in silty shales having various iron-oxide colors. As in the Wisconsin outcrops, they occur as spheroids loosely cemented with crystalline hematite, though the beds are so thin that only a relatively small part of a 5-foot well sample consists of such material. They are commonly associated with red to green weak silty clay that contains small pebbles and grains of weathered Maquoketa dolomite. In some samples they appear to occur in a yellowish brown silty clay which has a starch-like fracture and contains brown flakes, suggesting a soil zone. In one sample the spheroids occur in a very fine sandstone containing grains of dolomite, hematite, and a hematite-replaced spicule. All occurrences are in the midst of more extensive areas where the top of the Maquoketa is represented by red clay shale containing weathered dolomite fragments. Such red shale areas are present only where the Maquoketa reaches its maximum thickness of 190 to 250 feet, as may be noted by comparison with Du-

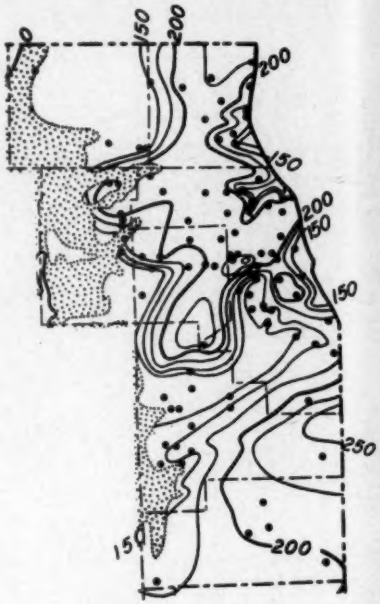

FIG. 5.—Thickness of Maquoketa formation in the Chicago region; isopach interval 25 feet (after DuBois).

Bois'[11] isopach map of the Maquoketa (fig. 5).

Elsewhere in Illinois Neda spheroids have been noted in two wells in eastern Whiteside County and in another in eastern Peoria County where the Maquoketa thickness is near a maximum for the region of a little more than 200 feet. All these conditions are interpreted as indicating that the Neda was deposited on a relatively flat surface of the Maquoketa and was eroded widely along with the Maquoketa formation in an interval previous to Edgewood deposition.

The iron-oxide spheroids in the matrix of silty shale of the Neda de-

[11] DuBois, E. P., Subsurface relations of the Maquoketa and "Trenton" formations in Illinois, Illinois Geol. Survey Rept. Inv. 105, fig. 1, p. 8., 1945.

FIG. 6.—(Left) Thin section of Neda iron oxide spheroids in matrix of silty shale from Illinois (X18).

FIG. 7.—(Middle) Broken surface of Neda silty shale showing spheroids altered to clay (X18).

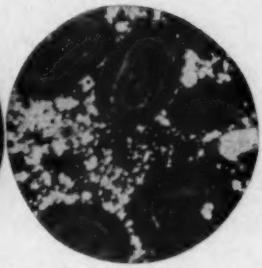

FIG. 8.—(Right) Thin section of Neda deposit showing spheroids replaced by calcite (X18).

posit in Illinois are generally smaller than those in Wisconsin, ranging up to 1 mm. in larger diameters, only a few reaching 1.25 mm. diameter, and averaging .75 mm. or less. They are similar in appearance to those in Wisconsin, being generally spheroidal and having smooth surfaces not only on the outsides of grains but on secondary surfaces made by breaking off the oolitic shells. Many of the spheroids in thin section show no nuclei, but the most common nuclei observed are fragments of other spheroids, especially fragments of the outer shells (fig. 6). A few were observed that were fragments of the matrix of silty shale, and a very few contained single silt grains or other material at the center. Most of them show a slightly darker brown outer hull.

Some observations of interest in considering the composition and geologic history of the oolites are as follows:

1. In the upper portions of outcropping Neda beds, varying in observed thickness from a few inches to as much as eight feet, the former oolites which were subjected to weathering previous to Edgewood deposition lost their iron-oxide content, leaving a residuum of clay (fig. 7). This clay has been identified by Grim[12] as illite. Usually its texture is dense and porcelaneous, showing only faintly or not at all the former concentric rings of the oolites. The dull olive-green color disappears on treatment of the sample with acid, leaving the clay almost white. These clay masses appear slightly smaller than the average iron-ore spheroid, and the shapes of the cavities in which they occur, though roughly spheroidal, are somewhat distorted, indicating that the sediments have been somewhat compacted to fill partly or entirely the former oolite spaces. However, it becomes evident that, because of the large amount of residual clay, some original spheroids were not highly iron-bearing. Some clay masses are soft and porous, and occupy proportionately less space than the dense variety in the cavity left by solution of the iron oxide. Some consist only of flat round blebs of green clay in sizes typical of the oolites. Evidently these last formerly contained high

[12] Grim, Ralph E., personal communication.

proportions of iron oxide before the iron was dissolved and the sediments collapsed.

2. Some of the former oolites contain partial replacements of gray crystalline calcite (fig. 8). The cleavage faces of the calcite are so oriented as to indicate that each oolite replacement developed as a single crystal. Surrounding the crystal mass is the residual clay. Some of the calcite masses occupy practically all the former oolites except the outer hulls, whereas others are smaller and the residual clay masses seem to be larger accordingly. It is suggested that calcite formation took place only after the cavities had been left by iron-oxide solution and that the sizes of the crystals were governed by the available space. Thus it would appear that the calcite deposited after the beginning of Edgewood time, possibly long after that time.

3. Some of the residual material enclosing the calcite grains has the appearance of perfect fragments of outer hulls of iron-ore spheroids except that they are dark brown to black, suggesting the presence of organic material. Kosanke[13] examined some of these and reported that they show no cellular structure but appear rather to be composed of amorphous material. Upon being heated in a test tube the black color disappears, leaving light-brown amorphous clay suggestive of that described by Hawley and Beavan as halloysite in the hulls of oolites in Wisconsin and of a somewhat different chemical character than the materials making up the remainder of the oolite.

The considerable variety of sedimentary materials in which the iron-ore spheroids are found, the occurrence of the spheroids in northeastern Illinois and elsewhere only where the Maquoketa is thickest, and recognition of the same type of iron-ore spheroids at about the same geologic horizon in widely separated areas from Kansas to Wisconsin and Illinois, suggest that the Neda formation was a widespread deposit of variable character lying upon known Maquoketa (Cincinnatian) shale, and was to a great extent eroded away during pre-Edgewood (pre-Lower Alexandrian) uplift. It appears significant for considerations of correlation that the Neda type of oolite occurs elsewhere in the eastern half of the United States in Silurian strata only, that is, the Red Mountain formation of Upper Alexandrian and Lower Niagaran ages in the Birmingham District, and the Clinton group of Lower Niagaran age in New York.

There is no difficulty in assuming that conditions of deposition favorable to the formation of Neda oolite recurred at intervals from late Cincinnatian to early Niagaran times, but in order to be sure that these conditions prevailed across the Ordovician-Silurian boundary the possibility should be examined that the Maquoketa fossils found in the Neda in both Wisconsin and Iowa may have attained their position by being reworked by an early Silurian sea.

[13] Kosanke, R. M., personal communication.

PHYSICS

SURVEY OF CITY NOISE

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A survey of city noise has been in progress in Chicago for over two years. The program covers noise of transportation vehicles, and noise in traffic lanes, industrial, and residential areas. The study is sponsored by Armour Research Foundation of Illinois Institute of Technology and the Greater Chicago Noise Reduction Council, and has the cooperation of the City of Chicago and the National Noise Abatement Council.

The work was undertaken as a public service and to stimulate further interest in the subject. Not only has the noise problem become more acute with the passing of time, but the public has become reconciled to noise as a necessary condition of present-day living. Furthermore, good methods of simply, rapidly, and reliably measuring industrial noise have not been available to the engineer. Equipment is available for measuring sound intensity, but acousticians agree that there is little correlation between sound levels, which are a measure of the physical condition in the medium, and loudness as adjudged by the human ear. It is hoped, therefore, that the results of the survey will create interest in further work, and will, in addition, establish a preliminary basis for tolerable noise levels which will be useful in writing or revising anti-noise legislation.

A study of city noise was made in New York City in 1930.* The results of this work were far-reaching and beneficial. Other surveys on a smaller scale have been made by a number of workers.

An important part of the present study has been that of taking octave band levels in addition to over-all levels. The over-all level is that indicated by a standard sound meter which responds to the entire audible spectrum within the limitations of the meter. The octave band levels are those read on the sound meter which has been modified by switching in various band pass filters. The meter then indicates the level within the particular band. The bands referred to in this paper are one octave wide.

Many acoustical measurements of mechanical noises have indicated the unreliability of the single over-all measurement to represent the objectionable degree of the noise. It is well known that levels in the various octave bands are more valuable in describing the noise than the single over-all level. As a result of numerous listening judgments on noises similar to these, it has been found that the loudness and objectionable nature of such noises could be correlated better with one of the octave measurements, such as the 400-800 cps band,

* *City Noise*, published by the Noise Abatement Commission of the City of New York, The Academy Press, New York, 1930.

than with the single over-all level. This particular band represents a good compromise between lower frequency octave levels with high energy content and higher octave band levels with reduced energy, because of the absorption by intervening structures and air.

Noise of Vehicles

The phase of the survey concerned with noise of common transportation vehicles was started first because vehicle and traffic noise was believed to be more objectionable and more prevalent than industrial noise. The work has been completed, and with curves and tables is rather comprehensively reported in the *Journal of the Acoustical Society of America*, Vol. 22, Number 2, March 1950.

Inside vehicles, the highest average levels were measured in subway cars. These were 95 db over-all and 91 db in the 400-800 cps band. All measurements are on the flat network. The lowest average levels were 85 db over-all in a new "L" car and 68 db in the 400-800 cps band measured in a relatively new seven-passenger sedan. Levels for such vehicles as old "L" cars, old street cars, trolley buses, PCC cars, motor buses, and suburban steam and electric railroad cars were between these maximum and minimum values.

Outside vehicles, the noise was measured at 20 feet in all cases except for railroad trains, in which case a distance of 100 feet was believed to be more practical for the purpose. The highest average levels were for subway trains and the levels were 94 db over-all and 87 db in the 400-800 cps band. The lowest average over-all level was 79 db for trolley buses. The lowest average level in the 400-800 cps band was 66 db for automobiles.

Traffic Noise

Although traffic noise generally is more intense than industrial noise, in many cases it may be adjudged less objectionable. This follows because: (a) the public may tolerate public transportation noise on the incorrect basis that it cannot be reduced, and (b) vehicle noise, aside from automobile horns, squealing brakes, and clanging street car gongs, when close to a listener, increases slowly as the vehicle approaches and then decreases. Industrial noise, on the other hand, often changes abruptly. Generally it stops and starts suddenly and may be objectionable because of its characteristic quality which identifies it as a forging hammer, steam exhaust blast, a traveling crane, a whistle, metal handling, or the like.

Measurements have been made at intersections and in thoroughfares to ascertain levels due to traffic. Insufficient data have been taken for a complete picture of the range of over-all and octave band levels. Based on the meager data, the over-all levels ranged from about 65 to 85 db, and the levels in the 400-800 cps band from 45 to 70 db. These figures are for places where a reasonable amount of city traffic, such as automobiles, trucks, and mass transportation vehicles, passes.

Industrial Noise

Another phase of the survey concerns noise in industrial areas. Over a hundred different places in the many Chicago industrial zones were visited and data taken during the usual business hours. Measurements were taken from the sidewalk, street,

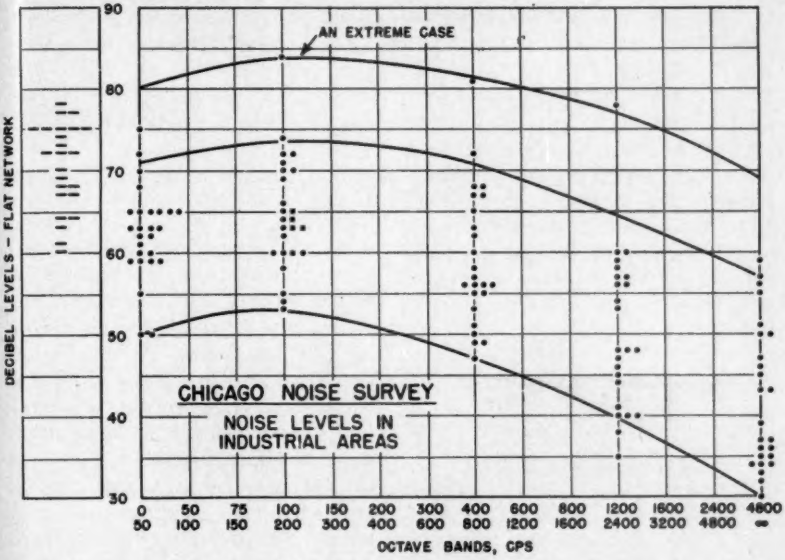

FIG. 1.—Data and curves of noise in industrial areas. Measurements (flat network) are on the sidewalk or street about 25 to 30 feet from buildings or plant boundaries and during usual daytime business hours.

or other public thoroughfare on the outside of each plant or industrial area. Distances generally were about 25 to 30 feet from a building or boundary. In many cases it was difficult to establish a meaningful sound level because of the intermittent nature of the noise. Information on whether the noise was above or below the general background noise also was noted.

Preliminary study of the data indicates a range in over-all levels of about 60 to 90 db. Measurements in the 400-800 cps octave band ranged from 45 to 80 db. Typical levels are shown in figure 1. This figure also shows the value of octave band data in describing the noise as compared to the single over-all level. Despite the incompleteness of these data, they have been used to make preliminary curves and draw preliminary conclusions. Figure 2 shows the distribution of noise levels measured in the 400-800 cps band. The curve shows that about 95 percent of the levels fall below 70 db. Assuming that these data are confirmed after complete analysis of the measurements, a preliminary conclusion might be drawn that 5 percent of the cases should be considered objectionably loud.

Figure 3 might be termed a preliminary limiting curve for industrial noise. It has the same general shape as industrial noise curves and passes through the previously mentioned 70 db level in the 400-800 cps band. It would define a noise spectrum such that industrial noise with higher components than those shown might be considered legally objectionable. Such measurements and curves require complete and careful analysis before conclusions can be made.

The study indicates one important observation even at the present stage. Industrial noise outside plants and factories is not so loud as it is reputed to be. The few factories that make intense noise probably have given a bad reputation to industry in general. Many cases were found where the plant noise could not be measured in the background of unidentifiable sounds or of transportation vehicle or traffic noise.

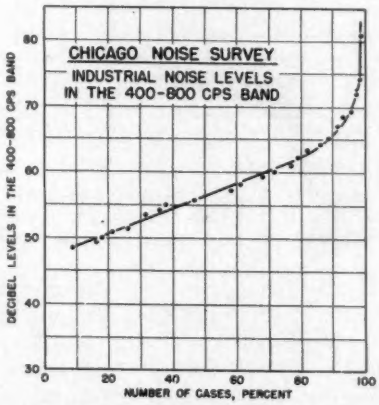

FIG. 2.—Curve showing the percentage distribution of industrial noise levels measured in the 400-800 cps band. From these data it can be seen that about 95% of the cases are below 70 db in the specified octave band.

RESIDENTIAL AREA NOISE

The data on residential noise are rather meager at the present time. The background levels are caused by industrial or traffic noise at different distances. Nearby vehicles, children at play, vendors, and other local sources generally do not contribute much to the ambient background, although they often are objectionable. Again, with incomplete analysis, the data indicate a range of from 50 to 80 db over-all and 35 to 70 db in the 400-800 cps band. As before, compromises are required in associating a single level with complicated noise conditions such as these.

AUTOMOBILE HORNS

An investigation of automobile horns is being conducted as a part of the survey. It was felt that such a study was of value because of the necessity for horns on vehicles and the objectionable nature of some of them. It is necessary that a horn be louder than the ambient background noise and even loud enough to warn nearby motorists in totally enclosed automobiles operating at noisy high speeds. Such warning signals, therefore, are required to be comparatively intense sound sources. On the other hand, many such horns are unduly loud. It is believed that horns can be effective without being raucous despite their relatively high levels. The work in progress consists in part in measuring the levels and in investigating the overtone structures to determine the characteristics of pleasant and effective signals on the one hand and characteristics which are objectionable and which possibly identify the horns as dangerous because of their frightening effect.

Again it must be reported that the work is not yet completed and only a report of progress can be made here. The modern automobile for the last five years has employed horns in pairs. The present work is simplified because most of the automobiles now on the streets employ only about half a dozen types of horns. The fundamental tones of the two horns in the pair are usually a musical major third apart. The more

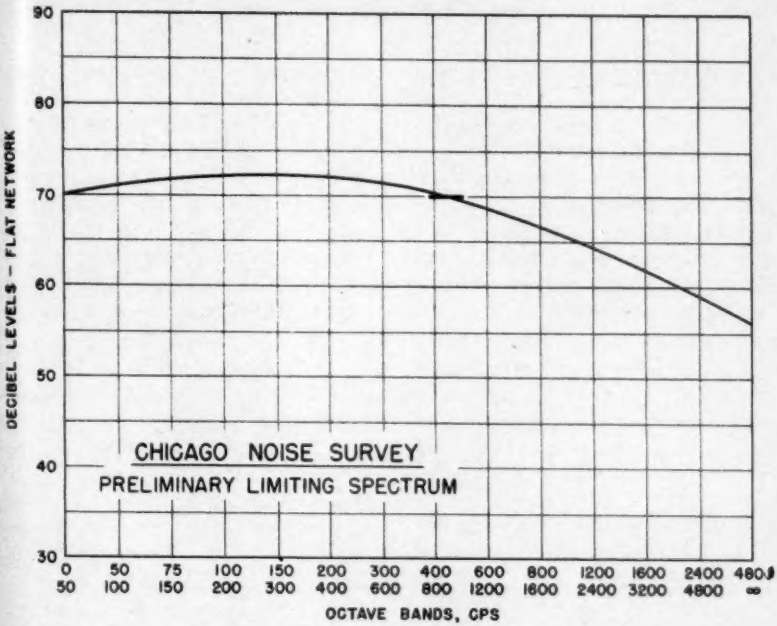

FIG. 3.—Curve showing a preliminary limiting spectrum. The curve is similar to others for industrial noise and passes through 70 db in the 400-800 cps band. Industrial noise data which are higher than this curve might characterize the source as legally objectionable.

pleasant sounding devices have harmonic overtones, whereas the objectionable sounding horns have inharmonic overtone structures.

Measured at three feet in front of the units, these horns have levels of from 105 to 125 db, so far as they have been measured. The fundamental tones for the different horns are in the range of about 150 to 400 cps.

An important feature of the work is that, in addition to the levels in decibels, the information in phons and sones also is being determined. There has been too little work done in the industrial field in the way of obtaining loudness and loudness levels. This has been due, at least in part, to the difficulty and the labor involved in determining these from decibel levels. As an example, the range of 105 to 125 decibels is a range in loudness level of approximately 125 to 140 phons and range in loudness of about 600 to 2000 sones.

It is desirable to define these units here. The loudness of a sound is the magnitude of sensation in the ear. It depends on sound pressure and on the frequency spectrum. The unit is the loudness unit or the sone. A 1000-cycle tone 40 db above the normal threshold has a loudness of one sone or 1000 millisones or loudness units. The loudness level of a sound is numerically equal to the sound pressure level in decibels of the simple 1000-cycle reference tone which

is judged to be equally loud. The unit of loudness level is the phon.

The program includes the processing of these horn noises in several ways, such as filtering the output to cut off at around 1000 cps. Again in a preliminary way, it has been found that such filtering removes a reasonable amount of the sound which is objectionable, and apparently does so without sacrificing the necessary warning characteristics.

Conclusion

The survey is proceeding at the present time with analysis of available data and with plans for the incomplete phases referred to above. Of more importance, further thought is being given to the problem of using these results beneficially. As the work becomes completed the results will be made available in the most useful way.

SPECTRAL CHARACTERISTICS OF FLASH DISCHARGES

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A "flash" discharge may be defined as an electrical breakdown produced by the discharge of a condenser through a gas at pressures of the order of 100 mm of mercury. It is characterized by a high current pulse of short duration accompanied by a brilliant white flash of light. The duration of the current pulse is of the order of 10 microseconds while the period of the light flash may be considerably longer, persisting for 100 microseconds or more in heavy discharges.

Many practical uses have been found for such lamps. Originally developed for high-speed photography and stroboscopic uses, they have more recently been employed in aerial photography, as a source of artificial sunlight in making moving pictures, and for emergency lighting of landing fields. Figure 1 shows several types of flash lamps. A, B, C, and G are forms of commercial photo-flash lamps; D, E, and F are examples of experimental models of flash tubes.

The maximum brightness of these lamps when used to produce single heavy discharges may exceed the brightness of the sun by a factor of ten with a peak flux output of a hundred million lumens. Currents of several thousand amperes are produced with instantaneous rates of energy input of several megawatts.

The physical characteristics of the emitted radiation are of considerable scientific interest. In the first place, the main component of the radiation is an intense continuum in the case of discharges where the current density is 20,000 amp/cm^2 or higher. This in itself is unusual, since normally a gas is expected to radiate chiefly bright lines characteristic of the excited atoms and molecules present in the discharge.

In the second place, the line spectra which appear superimposed on the continuous background exhibit many anomalies when compared to the lines emitted by low intensity arc discharges in the same gas. A study has been made of these anomalies, both with reference to the energy input per flash, and also as a function of time during the various phases of the flash. This paper attempts only a very brief summary of the results of this study.

The Continuum

When measurements are made of the energy distribution of the continuum in the "integrated" flash, a broad distribution is found as a function of wave length. In the case of intense discharge a maximum occurs at about 4500 AU, corresponding to a black body temperature of roughly 10,000°K. The radiation density values, however, indicate much higher temperatures.

Most theories agree in ascribing the origin of these continuous wave lengths to "free-free" electron transitions with ions in the high density plasma existing in these discharges, and also to electron-ion recombination, or "free-bound" tran-

COMPARISON OF XENON ARC AND FLASH SPECTRA
(3,500 to 6,200 A.U.)

λ(A.U.)	Spectrum I	Spectrum II	Transition	D.C. Arc	45 Watt Flash	720 Watt Flash	Xe*	Xe
6098		x	$(^3P)\ 5d\ {}^4D_{5/2} - (^3P)\ 6p\ {}^4P_{3/2}$			x	II	
6036		x	$(^3P)\ 5d\ {}^4D_{3/2} - (^3P)\ 6p\ {}^4P_{1/2}$			x	II	
5976		x	$(^3P)\ 6s\ {}^4P_{3/2} - (^3P)\ 6p\ {}^4P_{3/2}$			x	II	
5824	x		$1s_3 - 5X$	x				
5668		x	$(^3P)\ 5d\ {}^4D_{3/2} - (^3P)\ 6p\ {}^4P_{5/2}$			x	II	
5473		x	$(^3P)\ 5d\ {}^4D_{1/2} - (^3P)\ 6p\ {}^4D_{3/2}$			x	II	
5419		x	$(^3P)\ 6s\ {}^4P_{3/2} - (^3P)\ 6p\ {}^4D_{5/2}$		x	x	II	
5372		x	$(^3P)\ 6s\ {}^4P_{3/2} - (^3P)\ 6p\ {}^2P^o_{1/2}$			x	II	
5339		x	$(^3P)\ 6p\ {}^4D_{7/2} - (^3P)\ 6d\ {}^4D_{7/2}$		x	x	II	
5292		x	$(^3P)\ 6s\ {}^4P_{5/2} - (^3P)\ 6p\ {}^4F_{5/2}$		x	x	II	
5191		x	$(^3P)\ 6s\ {}^4P_{1/2} - (^3P)\ 6p\ {}^4D_{1/2}$			x	II	
5122		x	$(^3P)\ 6p\ {}^4P^o_{1/2} - (^3P)\ 7s\ {}^4P_{3/2}$			x	II	
5081		x	$(^3P)\ 6p\ {}^4D_{5/2} - (^3P)\ 7s\ {}^4P_{5/2}$			x	II	
5028	x		$1s_4 - 3p_{10}$	x				
4923	x		$1s_4 - 3p_9$	x	x	x		I
4917	x		$1s_4 - 2p_4$	x	x			
4884		x	$(^3P)\ 6s\ {}^4P_{1/2} - (^3P)\ 6p\ {}^4S_{3/2}$			x	II	
4844		x	$(^3P)\ 6s\ {}^4P_{5/2} - (^3P)\ 6p\ {}^4D_{7/2}$		x	x	II	
4843	x		$1s_4 - 3p_8$	x	x			
4830	x		$1s_4 - 3p_7$	x	x			
4807	x		$1s_4 - 3p_6$	x	x			
4734	x		$1s_4 - 2p_3$	x	x	x		I
4671	x		$1s_5 - 3p_8$	x	x	x		I
4624	x		$1s_5 - 3p_6$	x	x			
4603		x	$(^3P)\ 6s\ {}^4P_{3/2} - (^3P)\ 6p\ {}^4D_{5/2}$			x	II	
4545		x	$(^3P)\ 6p\ {}^4D_{5/2} - (^3P)\ 6d\ {}^4D_{7/2}$			x	II	
4525	x		$1s_5 - 2p_3$	x				
4501			$1s_5 - 2p_2$	x				
4481		x	$(^3P)\ 6p\ {}^4D_{5/2} - (^3F)\ 6d\ {}^4F_{9/2}$			x	II	
4415		x	$(^1D)\ 6s\ {}^2D_{3/2} - (^1D)\ 6p\ {}^2D_{5/2}$			x	II	
4393			$(^3P)\ 6p\ {}^4S_{3/2} - (^3P)\ 6d\ {}^2D_{5/2}$			x	II	
4386	x		$1s_4 - 4X$	x				
4384	x		or $1s_4 - 4Y$					
4331		x	$(^3P)\ 6p\ {}^4D_{3/2} - (^3F)\ 6d\ {}^4F_{7/2}$			x	II	
4194	x		$1s_5 - 4U$	x				
3968	x		$1s_5 - 4p_8$	x				

TABLE 1.

sitions. The latter mechanism would be expected to be the predominant cause of continuous radiation in the "afterglow," or decaying portion of the light flash which persists after current ceases to flow in the arc.

To obtain a complete analysis of the electrical and radiation properties of these discharges it is necessary to make measurements as a function of time during the very short period of the flash. This is difficult in the case of the ordinary spark discharge across a gap at atmospheric pressure because of the extremely erratic behavior of the spark. However, by employing rare gases to avoid chemical reactions, and pressures of from 25 mm to 100 mm Hg, it is possible to obtain highly reproducible flash discharges in repetitive operation. The flash can be initiated with great precision, and accurate reproduction of current, potential, and photo-current showing the change of radiation intensity with time can be obtained on the oscilloscope screen.

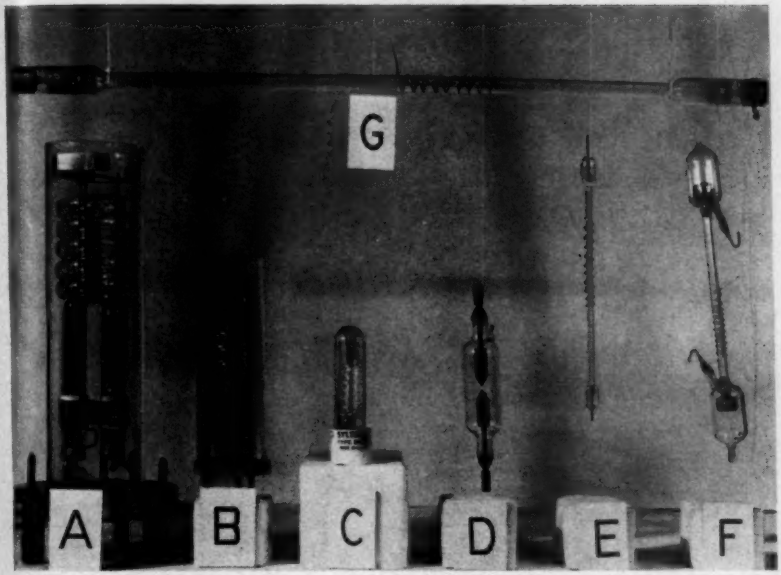

FIG. 1.—Types of commercial and experimental flash tubes.

Figure 2 illustrates how the current and the continuous radiation change with time for flash discharges in argon and neon tubes. These discharges are "triggered" by means of a sharp voltage pulse applied to an auxiliary electrode which causes enough ionization for a heavy arc current to form and discharge a condenser attached to the electrodes. These traces are taken from the oscilloscope screen.

Three types of phototube multipliers were used to register the intensity of radiation in three spectral regions: the ultraviolet (2400 to 4200 AU), visible (4600 to 7000 AU) and the near infrared (7000 to 12,000 AU). In obtaining these results the amplitude of each photocurrent plot was arbitrarily adjusted, so they cannot be intercompared. The total radiation in the visible and ultraviolet regions is much greater than in the infrared. It is noted that in all cases the peak light occurs much later than peak input current (or power), this lag being greatest for the longer wave lengths.

VARIATION OF CHARACTERISTIC LINE SPECTRA

A study of the line spectra is of particular interest to the physicist who desires information concerning fundamental processes occurring in this type of discharge. He wishes to determine the processes leading to breakdown of the gas, the current conduction mechanism, temperatures and ion densities in the column, the cause of the lag of radiation behind current, and the nature of the processes occurring in the gas plasma during the afterglow period. In general, our knowledge of the detailed processes occurring in the flash and spark discharges is quite incomplete compared to our

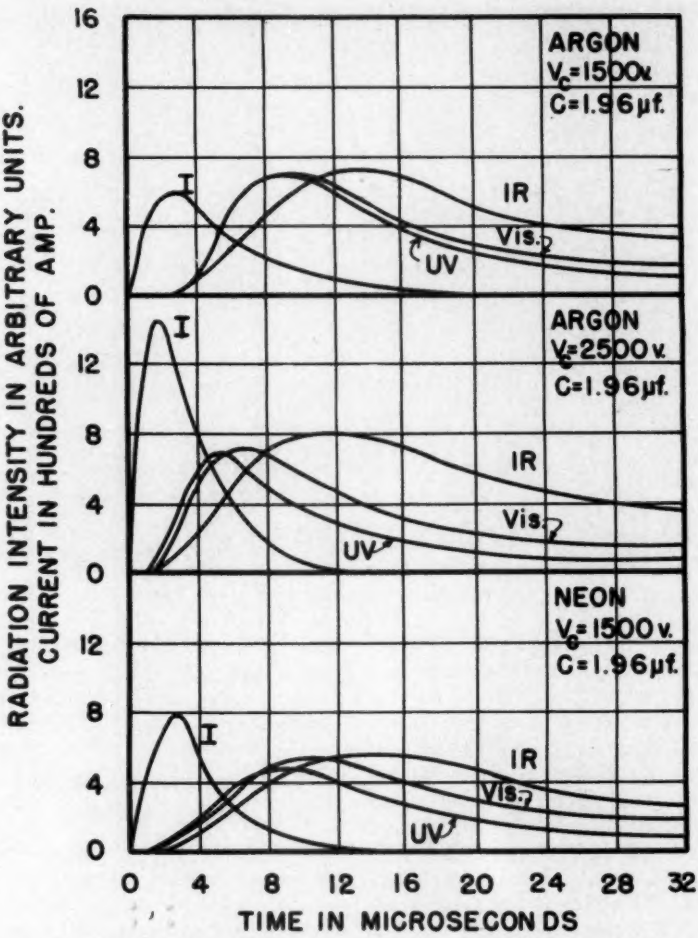

FIG. 2.—Oscillographic traces of current and radiation in argon and neon quartz flash lamps.

understanding of other types of steady discharges.

Spectrograms were made of discharges in xenon for the total flash period, and compared with the lines appearing in a low current steady arc discharge in the same gas. Table 1 gives a summary of results for the strong lines observed in the visible region. In the d-c low current arc only arc lines (Xe I) are observed. For low energy flashes a number of these same arc lines are observed, and in addition several spark lines (Xe II) appear, lines which are due to excitation of xenon ions. Lines appearing superimposed on the strong continuum in the high energy flash discharge are shown in the column on the right. Here only

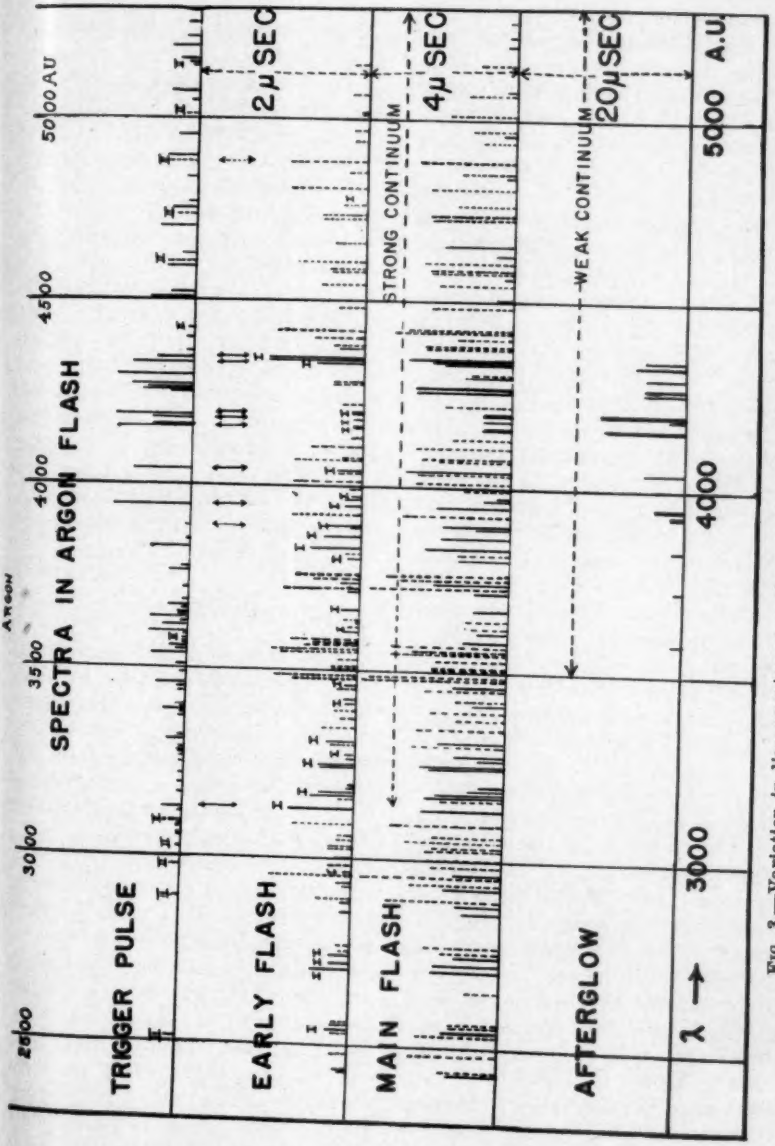

FIG. 3.—Variation in line spectra at various phases of a flash discharge in argon.

three arc lines show strongly, while twenty intense lines of the xenon ionic spectrum are identified. Similar results were obtained using other gases.

The question now arises as to how the spectrum varies with time over the entire flash period. A large number of observations were carried out using flash tubes filled with neon, argon, krypton and xenon. An example of such an analysis will be shown only for an argon-filled tube.

A method was developed for observing through a fine slit in a ten-inch disc driven by a synchronous motor, the light from the discharge at a given phase of the flash period. The particular instant in the flash when a spectrogram was taken could be varied by means of a phase changer which varied the time when the discharge was triggered with reference to the time of observation. The slit was of such a width that the observation interval was about three microseconds. Thus the emitted radiation could be photographed at any phase of the flash period in steps each three microseconds long.

Figure 3 is a chart of the results obtained using a quartz prism spectrograph. Relative photographic intensities for a given exposure are indicated by the height of the plotted lines. Solid lines are for atomic spectra (A I); dotted lines represent spark spectra (A II). The rate of synchronous flashing was one per second. However, for the weak light emitted by the trigger pulse, which occurs about 2 microseconds before the main current of the discharge begins, a higher rate was used with the discharge condensers disconnected. Thus, the exposure time for the upper section of the chart was about 300 times longer than for the other pictures. For the afterglow the exposure time was about 10 times longer than for the main flash.

The changes in relative intensities of the lines is very striking. Very few strong spark lines occur in the trigger pulse at high potential. At current peak (early flash) and at peak radiation intensity the line spectrum is predominately that of the spark, or second spectrum (II), of argon ions: some 44 relatively weak arc lines, compared to 71 spark lines of high average intensity. Late in the discharge only a few weak arc lines appear, the relative intensities of which are quite different from those appearing in the trigger pulse spectrum, or in the main discharge. The strongest set of four arc lines in the afterglow have very low intensities in the main flash relative to other lines appearing at the same time.

Conclusions

From this study of the spectral characteristics of synchronized flash discharges in rare gases the following conclusions may be drawn:

(1) The overall integrated line spectrum constitutes a small fraction ($<10\%$) of the useful light emitted by the discharge, the main radiation flux in the visible and ultraviolet regions being an intense continuum.

(2) In the short wave infrared region, measurements show that for heavy rare gases (argon, krypton, and xenon) the line spectra, consisting largely of arc lines, contributes about half the total light flux.

(3) The characteristic lines observed at the instant of peak radiation intensity are predominately those of excited ions, indicating the existence of a plasma having a high degree of ionization. Calculations

show that in the discharge column from 80 to 90% of the atoms may be ionized.

(4) The spectrum of the trigger pulse, excited when a 10,000 volt potential is suddenly applied to an external electrode, shows that high fields do not necessarily excite a strong spark spectrum. *Rather, a strong spark spectrum is characteristic of the high current, low voltage arc phase of the spark discharge.* Recent observations in high current steady arcs verify this conclusion.

(5) The presence of only atomic spectral lines in the afterglow indicates the absence of impact excitation at low electron temperatures. Here the lines arise from electron-ion recombination only, the relative intensities being characteristic of this process and quite different from those shown during the high-temperature phase of the discharge.

OPTICAL AND PHOTOGRAPHIC TECHNIQUES FOR THE SMALL-SCHOOL LABORATORY

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Most small schools and laboratories have more problems than money; this is often true of the large universities as well, but the small school is more handicapped when some special problem comes along because there is usually less likelihood of procuring equipment by interdepartmental exchange or loan. It is for this reason that the methods to be described are directed principally at the small school or laboratory.

It is rather remarkable that purely photographic measuring methods have not been more widely applied in research. Of course, there are many applications of photography in common use—to record images with the camera, shadowgraphs with the X-ray, spectrograms, and the like. However, the use of the photographic emulsion as a measuring element is still not extensive. Yet it can measure light-intensity, color, or any magnitude which can be expressed as either of these. It can measure things that the eye cannot see; and it can be applied to observe and record more closely, more accurately, and for longer periods than any individual observer.

The more flexible techniques of photographic measurement have been largely neglected; it is these that I want to describe today. There are a great many of them, and in the time allotted to me I can mention only a very few. I have chosen some which are more than usually varied, and which are especially susceptible to modification to other uses.

The motion-picture camera is often used to observe and to record the deflections of instrument pointers during tests; it is especially convenient for such things as aircraft tests, where the camera periodically records the indications of the entire instrument panel, and the films are later read visually. Prosperous laboratories often use recording oscillographic cameras to take down the data on electrical circuits. An early method of recording quantities with photographic means is shown in figure 1: a pointer-type instrument (which might be an electrical instrument, a pressure gage, or any instrument with an indicating pointer) which has had an opaque vane attached to its pointer and a light source so placed that the band of light passing through a slot in the dial is obscured by the vane as the pointer moves. The type of record produced is indicated on the slide—although of course the pattern does not show until the photographic paper or film is developed.

A record of this kind, or any variable-width record, is easily subjected to frequency or harmonic analysis. In many problems the periodicity of the magnitude being measured is important; the daily variation in earth-currents, the behavior of the tides or waves, the temperature variations in organisms, and many other phenomena are most interesting because of

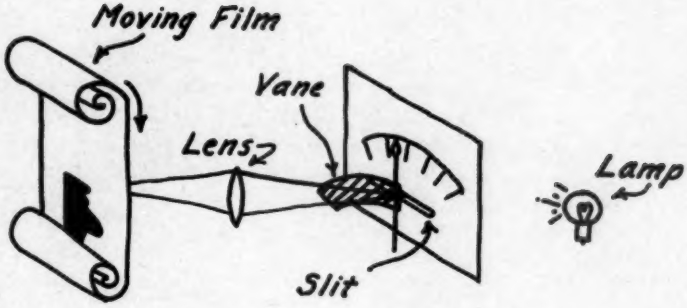
Moving Film
Vane
Lens
Lamp
Slit

Fig. 1

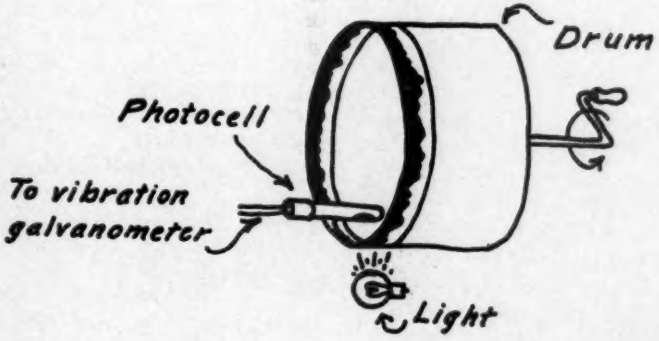
Drum
Photocell
To vibration
galvanometer
Light

Fig. 2

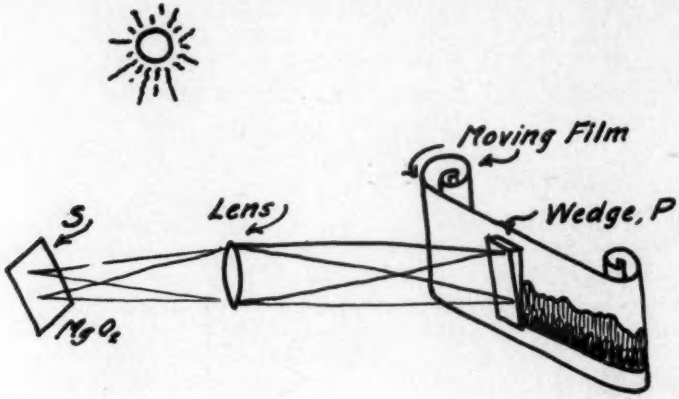

Fig. 3

their time-rate of change. Such a film record, taken over a period of days or even weeks, can easily be analyzed to determine what periodic variations may be present. It is only necessary to attach the strip of record to the edge of a cylinder which can be rotated (see fig. 2) while a light shines through the record and upon a photoelectric cell. The output of the photocell is then applied to some frequency-sensitive device; a tuned vibration galvanometer is ideal. When the speed of rotation of the cylinder is such that some component of the record comes by at intervals corresponding to the period of the galvanometer, a deflection will occur, and simple arithmetic is enough to determine the period of the phenomenon. Then other speeds of rotation can be tried until all frequency components desired are measured. Vibration galvanometers are not so common as they once were, but good results can be had with a simple tuned circuit and a vacuum-tube voltmeter or a cathode-ray oscilloscope, and these are becoming quite common in our physics laboratories.

This simple system is capable of many applications; there is a modification by which the periodic components may be evaluated by purely photographic means, but it is usually less convenient than the one mentioned. These systems, however, are only simple forms; they do not use the photographic materials in their most favorable manner.

In the following figures, there will be shown two sets of apparatus for recording sunlight and its characteristics; one records the average effective intensity, and the other both the intensity and the spectral composition or the color. The two pieces of apparatus were originally intended for use together, but can be used as individual items for their own purposes.

The first of these units (fig. 3) is for recording the effective intensity of daylight, continuously. It employs a clock-motor which moves a strip of 35 millimeter film at a rate of about 2 inches per day. Light

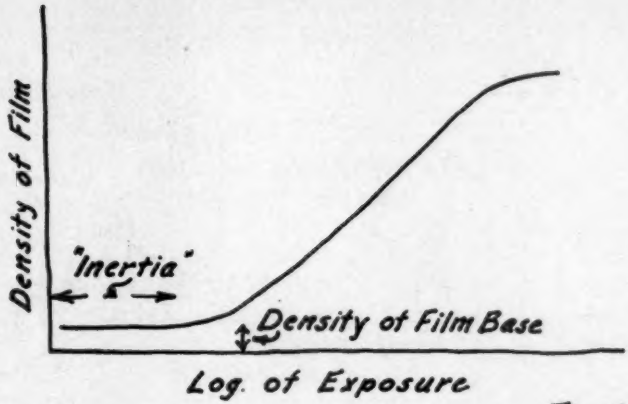

Fig. 4

from the sky falls on the surface S, which is of magnesium oxide, a neutral reflector; this light is reflected through the lens and through the gray wedge P_1 to where it falls on the film. The amount of light reaching the optical system depends of course on the intensity of the daylight, but the amount reaching the photographic film depends not only on that intensity but also on the density of the gray wedge. The over-all effect is that at some point along the length of the wedge the light intensity will be just enough to cause the beginning of darkening of the film. On one side of this point there will be perceptible darkening; on the other there will be no darkening. If a high-contrast film is used, this point is quite definite. A time-scale may also be applied to the film if that is desired.

Some of these things should perhaps be amplified before we go on to the next item. As most of us know already, the density of a photographic film (within its normal working range) is roughly proportional to the logarithm of the exposure. Below the working range there is an area where not enough light has fallen to produce a useful image. Actually, a certain amount of light must be received before any effect at all is produced; above this value the effect is proportional. This is called the "inertia effect" of the film, and it is this inertia or threshold point which is seen on the variably exposed film.

In figure 4 there is a curve showing the general shape of a density-versus-exposure curve for a film. What this means on the record is that the threshold point wanders across the film as the light intensity changes, and the boundary between clear film and gray film shows by its position the light intensity. It would be possible, of course, to permit the film to darken uniformly across its width, and to read its density with a microphotometer, except that most of us cannot afford a microphotometer. This system, in any case, makes a longer range of measurement possible.

The gray filter wedge used here is usually a piece of photographic film which has been partially exposed and developed; the exposure

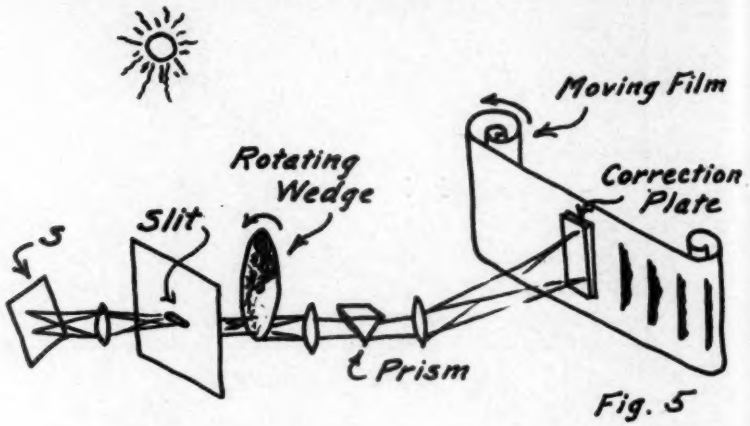

Fig. 5

is varied so that at one edge the wedge is clear and at the other edge quite dark. A density range of 0 to 3 corresponds to a range of 1000 to 1 in the amount of light transmitted. These filters can be made of gelatin, by squeezing a wedge of dyed gelatin between two thin glass plates, if neutral dyes are available. It is not difficult to make photographic wedges, but it is necessary first to prepare a curve like that in fig. 4, and then take data from it to calculate the exposures for the wedge. In all these procedures, conditions of exposure and of development must be controlled with some care.

The equipment for recording the color of sunlight is a little more complex. Again a clock-motor is used to drive the film, at about 2 inches per hour, but here a prism is used to spread a spectrum across the film, which must be panchromatic—approximately equally sensitive to all colors. The density of the various parts of the resulting band indicates the spectral composition.

To read this record, some device for measuring film density is required. The wedge method can be applied here; an easy way is to place a circular wedge over the lens, and rotate it about 10 revolutions per hour. This causes a uniform variation of intensity from very low to high, repeated every 6 minutes. The result is a series of repeated patterns along the film; the length along the film of the various elements of the pattern indicates the various intensities. The kind of pattern produced is shown in the figure; the actual films are easily read, but do not project well.

For ease in reading these records, it is desirable to equalize the frequency response, or the color sensitivity, of the film used. In figure 5 there is indicated a "correction plate" near the film plane. This plate equalizes the color response of the film. It can be made to match almost any commercially available film.

The actual response of a film to color is seldom uniform. Figure 6 shows a typical response curve; it is more sensitive to blue than the normal eye, and is also more sensitive to red. But within this range, the response may vary as much as 40

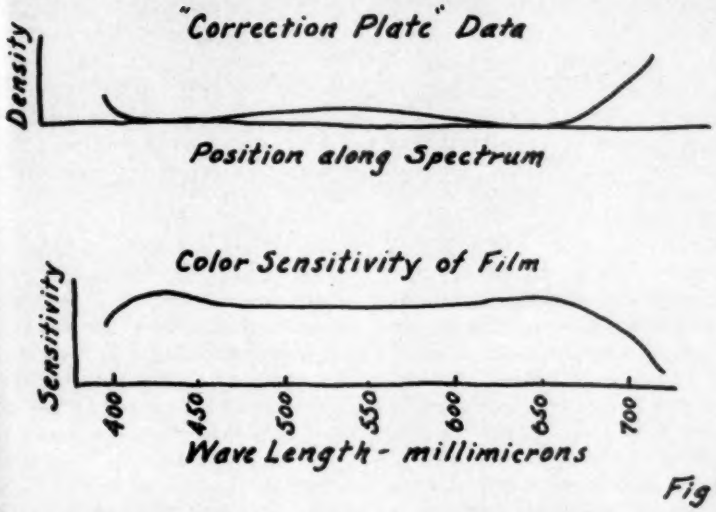

Fig 6

percent. This variation in response can be equalized by preparing a neutral density plate which matches the color curve for the film—that is, in the green, where the film is least sensitive, the correction plate permits most light to pass, but in the red range where the film is most sensitive, it cuts down the intensity. At any point, the sum of the two curves should equal the sum at any other point. The correction plate is placed close to the film; it is a neutral density filter, and its densities are adjusted according to the position of the color in the spectrum produced by the prism.

The optical quality required in these instruments is not very high; good results may be had with surprisingly crude optical systems. Reasonable care is required to avoid diffraction and reflection in unwanted places. The diagrams shown in the figures do not contain all the desirable operating details, such as the cylindrical lens just in front of the film in every case, but these details are obvious when construction is attempted.

The final accuracy to be expected from an instrument of this kind is not especially high, perhaps 5 to 10 percent. This is adequate for many purposes, particularly biological and agricultural studies. The range of intensities which can be recorded is extremely large; it is easy to handle a ratio of 10,000 to 1 because of the logarithmic scale. The actual method must of course be matched to the problem.

There are many other methods which might be described, such as force measurement either by Newton's rings or by the total-reflection method; the use of the Dove prism to extend the time range for recording with the cathode-ray oscilloscope; the photographic record from liquid-filled thermometers or manometers; and other types and classes of measurement. But these cannot be discussed in this paper; the few which have been selected will have to serve as examples of instances flexible enough to be applied in many other problems.

PSYCHOLOGY AND EDUCATION

VALIDATION BY MEANS OF THE SOCIOGRAM OF A TECHNIQUE FOR PROMOTING SOCIAL ACCEPTABILITY AMONG ELEMENTARY SCHOOL CHILDREN

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There is a growing emphasis both in educational literature and in practice upon social adeptness as a primary objective of education. Pressey and Robinson express this point of view in *Psychology and the New Education* when they say that "the guidance of social development along healthy and desirable lines might well be considered the first concern of modern education and the almost complete neglect of this problem the outstanding weakness of the traditional school."

All development is, of course, continuous, and social development is no exception to the rule. Yet the study of the child has clearly shown that certain developmental tasks belong specifically to c e r t a i n age ranges. In fact, without the successful completion of these various developmental tasks sequentially, whether they are physical, emotional, or intellectual, the child is tremendously handicapped in the process of growing into a balanced adult.

One of these developmental tasks that ideally is spread over the period of time from the entrance to school at the age of six till adolescence is the emancipation of the child from the circle of the family and his entrance into his peer group. In this new world to which the child goes it becomes increasingly important to him to find a place for himself where he belongs. In fact, it is a corrolary of the social adeptness objective of elementary education that the child can develop social adeptness only in a group where he is an accepted and contributing member. For the psychologist believes that the psychological environment of the child —the reaction to him of individuals and groups with whom he is in contact—is of infinitely more importance as a factor in his development than the physical environment in which he lives.

Grouping has generally been a tool that the elementary school of our age uses to promote its intellectual purposes and to aid in reaching such goals. But whether or not grouping is a tool for the school to use in achieving its social goals and especially whether *the type of group* is a major factor in the degree of success the individual achieves as he strives to attain status are problems not yet thoroughly investigated.

It is the hypothesis of this study that through considerable use of small informal flexible groups the child who is a fringer or an isolate can most easily be helped to gain in social acceptability and, as he does this, it is believed that he will be a better achiever intellectually.

This study makes no pretense at being a controlled educational experiment. It is rather a problem in teacher education in which all the teachers at a given grade level in

a small city in southern Illinois cooperate in an attempt to help children in their groups who lack social status to attain a higher degree of social acceptability.

It is an attempt, likewise, to put in the hands of the teachers a tool by which each may discover for herself whether or not she is succeeding in helping children who have not yet attained and do not know how to attain status in their peer group. Also, we believe it will throw some light on the effect of different types of groups on growth in social acceptability.

However, since the emphasis was to be teacher education, no attempt was made to force consideration of this problem until attention turned there naturally. As it happened, for several weeks other problems occupied the focus of attention.

The background for this study is laid in the work of J. L. Moreno and dates back about fifteen years. It was in 1934 that Dr. Moreno published his epochal book, *Who Shall Survive?* In this work he developed a science of sociometry—a way of measuring interpersonal relationships in a group—and used the sociogram as a way of recording and making graphic these relationships. Since that time Helen Hall Jennings and others have used the same technique to measure social relationships within a schoolroom.

Dr. Moreno used his new discovery not only as a means of measurement but also for therapeutic purposes. In his book he described the use of it in grouping girls in cottages in the New York State Training School for Girls at Hudson, N. Y., and reported substantial reduction in number of problem cases when groups were formed on the basis of information obtained by a sociometric test.

Fifth grade children were used in this study, since previous studies have shown that social relationships among younger children are very unstable. Reading was chosen as the special field for study because the capacity of social and emotional factors to affect a child's performance, while evident in most learning situations, is especially evident in the acquisition of reading ability. This is true at least partially because the attainment level in reading significantly affects every other type of subject matter. It is also true that society puts an especially high premium on reading skill in the child.

In the small city where this study has been carried on there are seven fifth grades with an average enrollment of thirty pupils each. All teaching, heretofore, had been conducted with an entire grade group with uniform assignments for every child.

The superintendent stated in a meeting of fifth grade teachers before the opening of school that the director of the study would be at the service of the teachers as consultant, that she would teach classes when requested to do so, and work with teachers either as individuals or groups in their attempts to meet pupil needs. Such supervision as would be given would be unofficial and would be actually educational leadership emphasizing in-service training of teachers. From the beginning, largely perhaps because of the confidence of the teachers in the superintendent and because of his evident interest in, and wholehearted backing of, the study, they accepted the offer of unofficial assistance in teaching problems with

little evidence of the resistance or even resentment with which supervision is sometimes met.

When the California Mental Maturity Test was given to all fifth grade children at the beginning of the school year, it showed a wide range of ability from school to school and within schools. Two groups had median IQ's of 110 and a range of points that exceeded 60. Four had median IQ's of 102-104 and a range of 50 points, and the seventh school had approximately the same range as the last four but a median from 13-15 points lower (89) than the four average schools.

On the basis of this wide spread of abilities the seven fifth grade teachers discussed individual differences and ways of meeting them. At this stage it was evident that most teachers were primarily absorbed with intellectual differences, but it appeared even then that at least one teacher was greatly concerned about emotional and social differences in her group.

When grouping was proposed as a way of meeting differences, it was decided to make a study of some attempts in this direction to see what light they might throw on the situation. Ability grouping and interest grouping both had advocates, but some teachers showed reluctance to shift from their old one-group procedure. It was agreed that each teacher in conference with her principal would decide which procedure to follow and report at the next meeting.

The report was as follows: Two teachers—one of a superior group and one of a near average group—decided to continue to use the grade group only, with uniform assignments for all, and attempt to provide for individual differences with directed out-of-school reading. Two other teachers—one of an average group and the other of the low group—felt that ability grouping in reading with material selected for each level so that each group would be able to read without strain would best help children to develop in reading skill.

The remaining three, while not experienced in interest grouping, were eager to try a procedure in which small informal flexible groups would function frequently.

By this time the Progressive Achievement Tests had been given to fifth grades and the results were available for all teachers.

Teachers of ability groups had decided to use only two groups. Children with a reading grade score of 4.5 or less would be provided with material with a simple vocabulary but with a high interest level. Others would read the basal text. Teachers using the single grade group only made use of the results to guide their children in selecting books for out-of-school reading. Those using interest groups likewise had the results of the tests at hand to help in wise selection of books.

The general plan followed by the teachers using interest groups in reading was: (1) the selection of a general subject by the group in cooperation with the teacher, (2) the division of the subject into its various phases, (3) the listing of questions to which the children wished to find answers on each phase of the subject to be investigated, (4) the election of student chairmen by the group, each to lead his group in research on one phase of the subject, (5) division into groups according to interests, (6) work in groups,

each child reading at his own level to help to answer the questions that had been listed earlier, (7) occasional meetings of the entire group to discuss problems of the grade as a whole, see a movie pertaining to the general subject, or evaluate progress, and finally, (8) some kind of pooled summary of the results of the research.

As each teacher followed her own procedure there developed a growing concern for the social development of pupils. Some study of Moreno's sociogram was made and the teachers decided to try a special modification of it as a means of measuring social status.

The three questions finally selected for the sociometric test to be used were by no means the only ones that might have been used and not necessarily the best ones. It was decided to use one question of a purely social character. "If your mother told you you might invite a child from your room home with you to dinner on Friday night and then to a basketball game, whom would you ask?" First choice, second choice, and third choice were called for.

The second question was on an academic basis, but called for cooperation between two people. "If you need help in arithmetic and the teacher, being busy, tells you you may ask a child in the room to help you, whom would you ask?"—again, first choice, second choice, third choice. The third question had to do with ability to fit into a group and contribute to the cooperative thinking and effort of the group. "Whom do you like best to have working on a committee with you?" In each case, as above, the child was asked to give first choice, his second if the first were absent, and his third if both the first and second should be absent.

There are some respects in which it may seem regrettable that the sociometric test results could not have been procured earlier in the year. However, since this study has been conceived as primarily one of teacher education, it has been a guiding principle not to use any procedures with the groups until the teachers were ready for them. Consequently school had been in session more than three months and each teacher had had in operation her chosen plan of grouping in reading for from 6 to 10 weeks before the first sociometric test was given.

The serious approach of the children themselves to the test and their whole-hearted cooperation in answering the questions was a matter of note. All seven groups had been taken into confidence as to the year's work to the extent that they knew their teachers and the director of the study were working together to try "to find out some better ways to work with boys and girls" and they referred to the sociometric test in that connection in discussing it, though they had been told that their teacher hoped that the answers would help her in trying to make them happy in their school home.

The teachers' meeting in which each teacher studied the sociograms showing interpersonal relationships in her own group was the most interesting of the year. Varying teacher attitudes were plainly evident. At least one showed a defensive attitude at first—"Some children just don't have what it takes." Another teacher noticed one girl, who showed up distinctly as a fringer, who she felt could be helped to attain status with her peers if given

a chance to help others in arithmetic. Another commented that she believed one boy would have been either an isolate or a fringer before he worked in a small group that prepared an Indian play to show the large group what they had found out about how the Indians of the Southwest lived.

Each teacher studied with interest the group of children who were lowest in social acceptability to try to decide what the cause was and what direction remedial work should take in each case. Each teacher agreed to try to find something each isolate or fringer could do well and see that he got praise for it. Each teacher also agreed to try to build up the ego of neglected children by giving each some responsibility. The question at this point was, "Would a child rise in social acceptability with his peer group as he appeared to rise in acceptability with the teacher?"

A survey of the sociograms taken showed that there was great difference in interpersonal relationships within the different groups at that time. The only sociogram showing a group where no child was completely neglected was one of the schoolrooms where small-group work had been frequently used in the entire program for ten weeks.

Perhaps it should be noted that this school had at least one problem in social acceptability that no other school in the city faced. A children's home that had operated in the city for years moved the first of October so that it was within the bounds of this last mentioned school district and four children joined the group from the Home. This teacher used considerable ingenuity in creating situations that would help the rest of the group to realize that boys and girls from the children's home were perfectly normal children like themselves. She arranged with the director of the Home to have some committees meet there on Saturdays. Since no child was allowed to leave the Home after dinner at night except by special arrangement with a responsible adult, she arranged at different times to have a parent of one of the children in the room call for one of them and take him along with his own child to a school program or basketball game. It is probably not assuming too much to say that the very satisfactory showing of these children on the first sociometric test can be attributed to these wise procedures, for there were many indications in the first days after these children joined the group that the others did not accept them without reservations.

The second sociometric study was made April 20. In order to be able to draw conclusions about changes in degree of acceptability, it was decided to weight the choices, giving six points for a first choice, three points for a second choice, and one point for a third choice. The small amount assigned to a third choice is justifiable because experiment has shown that the third choice is far less reliable than the other two. Most children will repeat their first and second choices if given a chance to choose again soon after the first opportunity, but will vary the third choice.

The short period of time since the last sociograms were made does not permit a full analysis of results, but such analysis as has been made indicates that there is a distinct difference in the changes in acceptability in the different groups.

Rather arbitrarily we have accepted ten as the dividing point among the scores of social acceptability.

TABLE 1.—NUMBER OF ISOLATES AND FRINGERS IN EACH OF SEVEN FIFTH GRADES IN WHICH VARYING GROUP PROCEDURES HAD BEEN USED THROUGHOUT THE YEAR.

School	Number enrolled	Median IQ	Range of IQ	Type of Grouping for Classroom Activity	Number with Social Acceptability Score Below 10					
					December 1			April 20		
					Isolates Score 0	Fringers Score 1-9	Total Score 0-9	Isolates Score 0	Fringers Score 1-9	Total Score 0-9
1	32	110	73-145	Entire grade	3	4	7	4	5	9
2	27	102	78-127	Entire grade	0	7	7	2	6	8
3	26	104	73-128	Small flexible groups	0	7	7	0	5	5
4	30	110	76-139	Small flexible groups	1	8	9	1	5	6
5	28	89	63-115	Ability groups	2	6	8	2	7	9
6	32	103	72-140	Small flexible groups	1	8	9	0	7	7
7	34	104	73-128	Ability groups	1	9	10	1	12	13

Those receiving less than ten points are either isolates (with zero scores) or fringers (with scores from one to nine). A score of ten means that a child has received one first choice, one second choice, and one third choice, or equivalent, whereas three times that many—three first choices, three second choices, and three third choices—would be the average each child would receive on the three questions of the test if the choices were evenly distributed.

The accompanying table indicates the status of each group at two different times during the school year, as revealed by the two sociometric tests. These groups are not matched. Many varying conditions affect each of them. The main objective has been to make teachers conscious of children's needs with respect to status in their peer group, and to interest them in trying specific ways of meeting those needs.

The rough data as it stands from seven unselected groups in the same community would appear to throw some light on the usefulness of small flexible groups to promote social acceptability among isolates and fringers.

Although the evidence is not overwhelming, there is an indication here that schools 3, 4, and 6 are improving social relationships by reducing the number of isolates and fringers. These schools are the schools that have made frequent use of small flexible groups. The increase in number of children with low acceptability scores in the other groups may be due to strengthening of clique lines where no special measures are used to change the situation.

There is nothing here to suggest that there is any distinct difference between ability grouping and the grade group as a tool for affecting social relationships. All groups have doubtless benefited by their attention to this problem. But it is evident that it takes more than attention from the teacher to cause a child to rise in status with his peer group.

While the success of such a program as this should never be judged in terms of what happens academically, it will be a matter of more than passing interest to discover whether the children who have improved in social acceptability may not also simultaneously have become better achievers intellectually.

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A STUDY OF COLLEGE SCIENCE COURSES DESIGNED FOR GENERAL EDUCATION

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This investigation was begun in the spring of 1948 and completed in the spring of 1949. It has been sponsored by the Cooperative Committee on the Teaching of Science and Mathematics of the American Association for the Advancement of Science.

The purpose of this study was to determine the status, trends, objectives, content, procedures of instruction, problems, and values for general education of college-level science courses which are especially designed for students who desire a general and not specialized training in science. Many of these courses have previously been designated by such terms as survey, generalized, orientation, integrated, or foundation. All of the above-named types of courses have had in common the inclusion of subject matter from more than one specialized field of science. In addition to these courses, the study includes single-subject courses that have been modified for the purposes of general education. All types under investigation are herein referred to as *general education science courses.*

In order to secure information on the types and prevalence of courses, an inquiry was sent to the administrators of 967 four-year colleges, universities, and teachers colleges in the United States. Replies were received from 660 schools. In addition, a survey of 600 college catalogs gave information concerning 60 more schools. Thus, information is available from 74 percent (720 schools in all).

To secure detailed information about the specific courses designed for general education, a seven-page questionnaire was sent to a selected group of 300 science teachers. Usable course descriptions were received for 150 courses distributed among 103 schools of all sizes.

The data supplied on the questionnaires were supplemented in a number of ways. For many courses either outlines, syllabi, textbooks, or published articles were available for study. Furthermore, the writer investigated by personal visits 28 of the 150 courses that were studied. A student opinionnaire was administered to 1200 students in 14 courses.

Of the 720 schools for which information is available, 59 percent offer some type of general education science course. Most of these schools offer courses that cover both the physical and biological sciences, although there are some that neglect one area or the other. General education science is much more prevalent in teachers colleges than in other types of schools: it is offered in over 80 percent.

A comparison of these figures with those of pre-war studies shows that g e n e r a l education science courses are now much more widespread than at any previous time. They have increased in number

rapidly in the post-war years. Furthermore, a majority of the schools that do not have general education courses appear to be interested in developing them.

Of course, there is some opposition to this trend. The most obvious reasons are the satisfaction with the regular introductory science courses for purposes of educating the non-science major, and the difficulty of securing qualified teachers for the newer courses.

Ninety-two percent of the courses are planned specifically for the freshman and sophomore years. About half the colleges require one year of science of the general student. The remainder require more, usually two years. Most schools require work in both the physical and biological sciences.

In classifying courses on the basis of content, four principal types are revealed: (1) the general courses which include materials selected from all the areas of natural science, (2) the courses including subject matter selected from the fields of physical science, (3) those with material from biological science, and (4) the courses in single subjects, as physics or botany. Few new courses of the first type are being organized. The single-subject courses are multiplying more rapidly than the other types, especially in the large universities. However, there are fewer of these courses than any of the other types.

The common methods of subject-matter presentation are, in their order of frequency: (1) the survey of the subject matter of the area covered, (2) the more intensive study of selected units from the subject matter area, (3) the study of selected problems, and (4) the historical approach.

In the 103 schools offering the 150 courses that have been studied in detail, the average enrollment in general education science was approximately 400 students per school in 1947-48. This represents about one-third of the freshmen and sophomores. In separate schools the number of students that take the courses varies from a small group to 100 percent of the students.

Individual course enrollments in 1947-48 ranged from as few as 8 to more than 4000 students. The largest enrollments were in the biological science courses; the smallest were in the single subjects. There was a somewhat larger percentage of men than women enrolled in the courses.

Approximately 75 different objectives were reported for the courses. Of these, 7 are especially prominent. They are, in the order of frequency of mention:

1. To develop an understanding of the scientific method and facility in its use.

2. To provide acquaintance with, or mastery of, the leading principles, laws, and concepts of science, particularly those that have a bearing upon the daily life of the individual.

3. To provide a core of scientific knowledge or to give a broad understanding and general knowledge of science.

4. To develop various scientific attitudes of mind and appreciations of the values of science.

5. To give an insight into the relationships between science and the problems of living and to develop the ability to apply scientific knowledge to the solution of these problems.

6. To develop a greater joy in living through a more complete un-

derstanding and appreciation of the natural environment.

7. To stress cultural aspects of science and to show how science has contributed to civilization.

A majority of the teachers reported clearly defined objectives that are compatible with the main purposes of science for general education. However, in some courses there were apparently no special objectives beyond the desire to teach science.

The most frequently used methods of determining subject-matter content are, in order of prevalence:

1. Determination of the needs of the students.
2. Selection of a textbook.
3. The interests of students in the class.
4. To survey a field of science.
5. Analysis of the objectives and how to accomplish them.

The subject matter of the biological science courses varied widely, as did that of the physical science courses. There seems to be no ideal content for a general education course in science. Teachers have yet to agree upon any one common core of factual material, or upon a uniform method of presentation. Probably neither is to be desired.

Although many of the teachers in charge of general education courses are scientists and educators of note, a majority of the teachers in the courses do not have a Ph.D. degree and are in the lower professorial ranks. Twenty-two percent are assistants with no rank. Only 40 per cent are employed specifically for general education and only 30 percent devote full time to this work. Ninety-one percent of all teachers are specialists in one or another of the fields of science. Very few received college training designed to prepare them for teaching general education science.

In considering the common characteristics of the courses, we find that the typical course is one year in length and offers three credits per term. It is given by two or more teachers who use demonstrations, visual aids, field trips, and laboratory exercises in addition to lectures and discussions.

The most important problems that arise in giving general education courses are concerned with procuring teachers, providing suitable laboratory experience, securing acceptable textbooks, and selecting and limiting the subject matter.

There is considerable but not universal enthusiasm for the general education type of science course. In schools where such courses exist, the administrators, above all others, favor them. The courses in most schools were inaugurated by deans or presidents.

Among college faculties opinions vary from energetic advocacy to definite antagonism and from strong interest to a complete lack of understanding of the nature of general education.

A large majority of the persons who teach in the courses like them and work diligently to make improvements. Some teachers have been assigned the courses against their will; in the main, these teachers are subject-matter specialists whose interests lie in their specialties. Also they feel that they are inadequately prepared for teaching in a broad field of science.

Among science teachers there are some who oppose the general education courses because they take students away from their own speci-

alized courses. On the other hand, there are those who believe that the general education courses are an excellent means of interesting students in following a scientific career.

There is a tendency for some scientists to look down upon the courses and their teachers. This attitude may have been justified in former years when the courses were sometimes elementary and superficial, and the teachers poorly prepared. Although these conditions still exist, they are not common. Most of the courses are well developed and many of the teachers rank among the best.

The teachers report that most of the students like the courses. Various student appraisal studies corroborate this viewpoint. However, there are some students in every course who dislike science or find it difficult.

In the student opinionnaire investigation, 77 percent of the students rated the courses above average in the choice and use of the instructional materials and procedures. Seventy-five percent said the courses were above average in imparting useful information. Fifty-six percent rated the courses above average in making a positive contribution to their college education.

Most of the students were enthusiastic about their teachers. Eighty-eight and 85 percent respectively rated their instructors above average in knowledge of subject matter and in enthusiasm for their courses.

In general, the courses, the procedures of instruction, and the teachers were given a high rating. The conclusion must be drawn that a large majority of the students believe the courses to be highly satisfactory.

General education science is rapidly occupying a position of importance in college curricula. It is growing in prevalence, popularity, and respectability. Ambitious young science teachers can expect to look to this field for a career that will offer the same rewards as a teaching career in one of the separate sciences.

In this relatively new area of science teaching there is a tremendous challenge to teachers to perfect techniques for presenting science to the non-scientist. On all sides the challenge is being met by teachers who are improving old procedures and experimenting with new ones. From their efforts are coming methods that will be of value in all types of science courses.

General education science is firmly established and widely accepted. We can confidently expect that in the near future there will be an even greater extension of the courses in American institutions of higher education. In this scientific age, we can look forward to an increase of literacy in science that will benefit both the individual and society and smooth the path for the progress of science.

SOCIAL SCIENCE

SOCIOLOGICAL PROBLEMS IN THE STUDY OF INDUSTRIAL RELATIONS IN ILLINOIS

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The problems and areas of research discussed in this paper are the result of my own experience and reflection in the past three years, during which time I have been a sociologist on the staff of the Institute of Labor and Industrial Relations at the University of Illinois. The research carried on there has involved the collaboration of economists, political scientists, psychologists, and sociologists. The problems which I discuss are influenced by these related social sciences and may appear at first glance to be rather foreign to sociology as it is commonly understood.

Careful studies in the sociology of industry are a new development which has come about since 1940. There is still a great deal to be settled about the relationship of this new area to the older branches of sociological theory. It is not my intention at this time to go into this somewhat academic matter, but rather to point out a few of the substantive areas of investigation which seem to present promising lines for empirical research.

In speaking of industrial sociology in Illinois, I am referring specifically to the down-state or non-Chicago region. I do this for two reasons: first, Chicago is relatively better known through earlier research and is currently being studied by Northwestern University and the University of Chicago while the University of Illinois is the only institution (that I know of) which is studying the smaller cities and the rural areas; second, the Chicago area is so different in size, in population characteristics, and in the development of industrial relations that it is best treated as a separate category. What I have to say, therefore, is intended as a guide to those persons who may be interested in the sociological aspects of business and industrial relations in the down-state region.

Before one can assess the importance and magnitude of these problems, it must be understood that the entire character of the down-state region has been rapidly changing in the past three or four decades. Many people still think of the Chicago—down-state distinction as primarily a difference between a large city and a rural district; but this is no longer true, since a majority of the down-state population are town dwellers. This majority is increased if we add to it the large number of persons who live in the country but make more than half their living in some nearby town, and are therefore economically dependent upon manufacturing or commerce more than upon agriculture. The growth of cities like Decatur, Peoria, and Rock Island has produced the same kind of political and social division between city and the local country dwellers which is found on a larger

scale in the great metropolitan centers. The expansion of industry in down-state communities has resulted in the development of attitudes toward political and economic issues which are more nearly similar to those in Chicago or other big cities than they are to the attitudes in the surrounding rural areas. This has broken up the old unity of opinion which was based upon common regional interests.

While the growing similarity of all cities is of significance, there are at the same time important differences between down-state communities and Chicago which must be recognized. The relative newness of industry in the smaller cities has emphasized the difficulty of making over a town to an industrial base from the older trading center and "county seat" type of life. The rapid growth of trade unionism has similarly forced a rapid change in business practices and in community organization. This process of urbanization is still progressing rapidly and is the source of many of the so-called social problems which are currently faced by our towns and cities.

One of the topics which invites study is the organization and administration of small-scale businesses and small manufacturing establishments. We know a great deal about the ways in which large corporations conduct their operations; we know a lot about the problems of administration and supervision in mass-production factories; and we know a good deal about labor-management relations in big companies. This is in part because large enterprises naturally attract attention, and also because the large companies have recognized the need for studying their human relations problems. However, we have practically nothing concerning the hundreds of small and medium-sized companies which face comparable difficulties.

The research in this field which is now being carried on at the University of Illinois by the Institute and the College of Commerce is in a sense pioneer work; it must go much farther and must be supplemented by the efforts of other schools before we shall have an adequate understanding of the problems and practices of the small business man.

It is commonly said that one of the reasons for bad employer-employee relations is the large size of many companies. If this is true, then relations in small companies ought to be good. To date, however, we do not know if this idea is valid, and we shall not know until we have studies of many small companies. There is another reason for examining closely the sociology of the small business concern. This kind of business is probably the most seriously affected by depressions and labor turnover. Anything which will contribute to stabilizing these companies will, in turn, help to stabilize employment in general and community well-being. The sociologist can make a contribution by finding means to improve personnel practices and employee relations generally.

A closely related field of study is the nature of collective bargaining in the smaller company. Here again, we know very little. We suspect that the process of reaching agreement between union and management in a situation where owners and management are present, and consist only of one or a few persons, is quite different from the situation in a large company where the owners are absent and management is a

very large and complicated group of persons. A further complication lies in the fact that most small companies and union locals follow patterns set by the larger industries and in a sense, therefore, do not develop original or local patterns. Absentee control is important in both management and union for it reduces the independence of local representatives on both sides. In certain industries, absentee control has been carried to the point where labor contracts are made in the larger cities, and neither local employer-managers nor workers have much to say about the terms under which they operate.

Another large and important field of study is the structure and operation of trade unions in the smaller community. Organized labor has expanded greatly even in small towns in the last decade. The magnitude of this development can be seen when we consider that in many industrial towns at least half the total population are either union members or belong to the families of union members. In coal mining communities, especially, union affiliation may go as high as 90 percent of the population.

Three subdivisions can be stated within this general area of study. One is the changing attitudes in the working population, which have underlain this rapid acceptance of the union movement. This is especially important in the down-state area, which not so long ago was thought of as a non-union conservative region in which most workers reflected a rural or small-town orientation toward economic matters. The shift toward unionism is an expression of the growing urbanization of down-state people, including many of the rural dwellers.

A second approach to the study of unionism is the examination of the internal organization of unions at the local level. We know even less about the operating practices and problems of unions than we know about small business. Since the two are closely related, we cannot adequately understand one without considering the other.

A third aspect of unionism is its impact upon the social structure of the smaller community. Because of the newness of unions in most of the down-state areas the impact of their large scale organization upon the community at large has not been felt to the same extent as in larger centers where the unions are better established and more mature. However, the beginnings of union interests in community affairs can be seen in their concern with schools, local taxation, and the community chest. This interest will almost certainly expand, and the unions will very likely occupy a key position in such matters, since they are the only organizations which represent large numbers of workers, and can mobilize mass support for efforts in the civic field.

A more general problem is that of the population change brought about by the establishment of new industries and the decline of older ones. This is well illustrated by the current efforts to secure new and diversified industries in southern Illinois to replace the declining coal mining industry. In this region the only alternative to new types of employment is wholesale migration to expanding communities where there are opportunities for employment. This same problem can be found in less exaggerated circumstances throughout Illinois. It is a problem which has attracted serious attention on the part of those concerned

with the declining importance of the small trading center. There is today practically no part of the state which is not dominated commercially by a larger city. The result of this has been that many smaller towns which were based upon trade with the surrounding countryside have lost their economic base and must either decline in size and become ghost towns or find some new means for supporting their population.

The background characteristics of the down-state population are being steadily influenced by our industrialization. The area as a whole has never received large numbers of immigrants from eastern and southern Europe as has been the case with all of the cities in the East and metropolitan areas such as Chicago. There are a few special instances in which "foreign" groups have entered down-state Illinois. One of these ethnic elements is found in the Polish foundry workers who are present in almost every community where such employment is available. A second example are the Polish and Silesian coal miners who have come with the Scotch-Irish, English, and Welsh miners. Except for these specialized groups, the down-state population is a rather homogeneous combination of Anglo-Saxon and German, with a considerable Scandinavian group in the northern part of the state.

This population is being steadily augmented by migration into the area from the border states and from the deep South, of both white and Negro. The increase in the Negro population of many cities causes racial tensions and legislative efforts to stabilize the situation. Negro workers are entering industrial communities in response to the occupational opportunities presented to them. In general, they fill those jobs which are considered too low in pay or too undesirable to attract native white workers. In this sense, they are filling the position in Illinois industry which was filled by the eastern Europeans in the industries on the Atlantic seaboard.

The white migration is numerically much more important than the Negro. The wave of settlement from the border states, in particular, has now been noticeable even in the northern cities of Illinois, although it is greater in the southern part of the state. The Southern whites, like the Negroes, enter our industrial system in the lower occupations, but unlike the Negroes, the Southern whites have relatively little difficulty in moving upward into better jobs. The general acceptability of the white immigrants is highest in the southern half of the state, where the cultural differences between immigrant and native are so slight as to be of no real importance. The magnitude and continuity of the white immigration is such that if continued it will result in a new and even greater homogeneity of background of the native white population of all down-state Illinois and will quite possibly bring about a shift in the general culture toward that which now exists in the border states to the south.

The topics I have mentioned range from very specific matters of industrial relations in the small company, up to very general considerations of population changes in the state. I have brought them together in this paper because in my opinion they all represent social phenomena related to industry which can be profitably studied by the methods and concepts of sociology. In my opinion, all

these problems can be analyzed within the existing theoretical framework which sociology has established, since they all involve the common substance of human life, namely the organization of social structures, the functions of leadership and administration within these organizations, and the cultural values which people hold. A beginning has been made in the examination of each of the topics which I have mentioned, but it is only a beginning. The major part of the study lies ahead.

Every trained person, regardless of where he may be in the state, can make a contribution to one or more of the lines of the proposed research. We can accomplish an understanding of these matters only through the collaboration of many persons in many institutions throughout the state, all focusing their attention upon the common set of problems.

THE RELATIVE POWERS OF NATURE AND NURTURE: MONOZYGOTIC TWINS

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Although the "twin method of study" provides an ideal set-up for the investigation of the problem of "nature and nurture," egregious blunders have often been made in regard to the diagnosis of monozygosity.[1] A number of writers have failed to grasp the fact that it is not easy to determine whether single sexed twins are monozygotic or dizygotic. Precisely and scientifically speaking, there is only a very high degree of *probability* that some similar-sexed twins may actually be monozygotic. This degree of probability is sometimes so high as to amount almost to certainty. As everyone knows, monozygotic twins must be of the same sex since they are "derived from a single fertilized egg-cell which later splits into two parts, each developing into a complete child."[2]

The hasty investigator of the problem of "nature and nurture" is all too prone to seize upon one characteristic as a "proof" of monozygosity, thus speeding up his work but also vitiating its scientific validity. If twins are born with a single chorion, it is often assumed that this "proves" that the twins are identical. The common chorion is, indeed, an indication of monozygosity. It is not, however, a proof, because it is possible for the "chorions of two germs developing close together" to fuse.[3] Thus dizygotic twins may, and sometimes do, have a common chorion. It is almost impossible to tell at the time of birth of twins whether they are "identical" (monozygotic) "because important characters have not yet developed."[4]

In point of fact, monozygotic twins, at the time of their birth, tend to be *more* different than fraternal twins, in respect to weight and length, on account of prenatal conditions. The reason for this is quite obvious. When two fetuses develop in one single chorionic sac, one is generally in a more favorable position than the other and consequently is more advanced at the time of birth. By the time the single-chorion twins have reached adolescence, the identical hereditary set, if it actually exists, will have produced two human beings so much alike, in their physical characteristics, that they will be very frequently mistaken for each other, even by close friends, at first glance. Closer observation will reveal that the color of the eyes, the implantation of the hair, form of the skull, the color and vasculation of the skin are strikingly similar.

An interesting factor has recently been introduced into the diagnosis of monozygotic twins by the use of the electroencephalograph, an apparatus designed by Berger in 1929. It had of course long been known that the brain controls the body. Berger was

[1] See H. H. Newman, *Multiple Human Births*, New York, 1941.
[2] A. B. Fortuyn, "Modern Research on Identical Twins," *Quarterly Review of Biology*, vol. 7, 1932, p. 298.
[3] *Ibid.*, p. 300.
[4] *Ibid.*, *loc. cit.*

the first to record, efficiently and precisely, the minute electric discharges occurring in brain cells, active or at rest.[5] These tracings are known as electroencephalograms or "brain waves." By 1935 the interest of a number of scientists was aroused by the unique problem of monozygotic twins in relation to the similarity or dissimilarity of the recorded "brain waves."

In recent years electroencephalograms have been made of a large number of fraternal and identical twins. Usually, but not always, those twins previously regarded as monozygotic, on the basis of the single chorion and other factors, showed identical "brain waves" when the "E.E.G." test was administered.[6] In the case of the XY twins, one of the pairs personally studied by the present writer, not only was there a single chorion and also, after early childhood, so marked a degree of physical resemblance that even their closest friends frequently mistook one for the other, but also a complete identity of the "brain waves" as recorded by the electroencephalograph. In such a case it is safe to assume, without violating the canons of scientific precision, that these similar sexed twins are monozygotic.

In 1938 a careful study of personality differences between monozygotic twins was published by Dr. Evelyn Troup, who selected 20 pairs of identical twins in the city of Buffalo and tested them by means of the Rorschach method. Dr. Troup, who was fully aware of the difficulty of diagnosing monozygosity, used single-sexed twins previously regarded as identical *only* if at least eight definite criteria of monozygosity were present. Although these criteria did not include the electroencephalographic recordings, it is fairly safe to conclude that the 20 pairs of twins selected were actually monozygotic. The results of Dr. Troup's experiment coincided very closely with the findings of the present writer. The sample is, of course, too small to warrant any definite conclusions along statistical lines. The value of her study lies in the individual case histories. An analysis of the 20 cases studied suggests the following conclusions:

(1) Owing to the genetic set-up, there is a basic physical and temperamental similarity between "identical twins."

(2) There is frequently a marked difference in personality structure even in two such "identical" human entities as monozygotic twins. This difference appears clearly when the Rorschach test is given.

(3) The popular stereotype of identical twins is usually erroneous. This stereotype represents monozygotic twins as an inseparable couple bound together by common interests and close ties of affection. Since such pairs attract attention at first glance, an undue importance attaches to them. Only two of the pairs studied by Dr. Troup corresponded to this popular stereotype. The remaining eighteen showed such wide variance in personality structure and interests that her conclusion was that "the total personality pictures of the members of each pair indicated in general no high degree of resemblance."[7]

In one of the pairs tested by the

[5] W. G. Lennox, E. L. Gibbs and F. A. Gibbs, "The Brainwave Pattern, an Hereditary Trait. Evidence from Fourteen 'Normal' Pairs of Twins," *Journal of Heredity*, Vol. XXXVI, No. 8, August, 1945, p. 233.

[6] *Ibid.*, p. 234.

[7] E. Troup, "A Comparative Study by Means of the Rorschach Method of Personality Development in Twenty Pairs of Identical Twins," Genetic Psychology Monographs, Vol. 20, No. 4, p. 544.

Rorschach method there was not only a marked personality difference but also a strong hostility between the two members. Both the personality difference and the hostility were quite clearly the result of "nurture" rather than "nature." Although this particular case is definitely abnormal both in the statistical and the medical sense of the term, it is worth mentioning because it uncovers the problem of antagonistic monozygotic twins, a problem ignored by Newman. Furthermore, it sheds considerable light on a feature which is nearly always found in normal family life, namely, the tendency of children to compete with one another for the mother's affection.

The mother of the eleven-year-old girl twins designated as A and B in Dr. Troup's study of personality development was, in 1934, in a New York State hospital. Her case had been diagnosed as dementia praecox, paranoid type.[8] In 1936 she was sent home, under medical supervision. The twins were living at home, together with the other seven children in the family, when Dr. Troup administered the Rorschach test. The father was regularly employed as a mechanic. Both parents were born in Hungary and had come to the United States in early childhood. The twins' mother had married at the age of seventeen. She expressed dissatisfaction with her marriage and constantly accused her husband of infidelity. During the two years of her hospitalization, the twins had been placed at first in a foster home where both made a very satisfactory adjustment. After a few months they were sent to an orphanage, where the other children had already been placed.

After the mother's release from the hospital, arrangements were made for her to visit the children. It was during this period that the differences between twin A and twin B became apparent. The Sisters reported that twin A became "jumpy" when the mother appeared. She begged to be taken home. Her school work began to deteriorate; she "withdrew into herself" and displayed symptoms which were diagnosed as possible chorea. Her request to return home was granted. Twin B remained in the orphanage for a few months longer. When both twins were home the mother reported that she had no difficulty with twin B but claimed that twin A was "nervous, had terrible dreams, and was afraid to take a bath in a tub." She quarrelled constantly with twin B and also with her younger brother. She told her mother:

"I'm the black sheep. You like [B] better."

Twin A was taken to a child guidance clinic, where the psychiatrist was impressed by her "marked feeling of inferiority, both socially and academically." His opinion was that the mother had rejected the child and tended to identify her with the mother's husband's sister who, according to the mother, was "queer" at one time. Both twins were of normal intelligence, the I.Q. tests being recorded as 101 for twin A and 107 for twin B.

The Rorschach tests administered by Dr. Troup showed a marked similarity in the temperament of twin A and twin B. There was, however, so great a difference in the emotional structure of the two girls that she concluded that this case showed "how different the quality of personality make-up in a pair of identical twins with similar basic per-

[8] *Ibid.*, p. 497.

sonality constellations"[9] may become under certain circumstances.

The Rorschach tests of twin A indicated greater "sensitivity," a strong tendency to "retreat into introversion," together with a "more vital and colorful mental life" than in the case of twin B. Twin B was adjudged, on the basis of the Rorschach tests, to have "apparently succeeded in covering up the danger of the over-development of the whole inner life by an analyzing attitude."[10] Both twins showed a tendency towards introversion. The personality differences were clearly a result of subtle environmental differences.

Less clear cut, but indicative of similar conclusions, is the case of the twin boys designated as K and L in Dr. Troup's study. Their age, at the time of the experiment, was eleven. Their parents were born in Germany. The father was regularly employed, and had five children at the time the study was made. The home was of average comfort.

Unlike some of the other twins studied by Dr. Troup, twins K and L were scarcely ever seen in each other's company. Twin K, who, according to the results of the Rorschach test, had passed beyond the pre-puberty stage and had entered "the introversial swing typical of the climax of puberty,"[11] spent most of his time in the home taking care of his younger sister. Twin L, on the other hand, who was aggressively friendly and sociable and assumed all responsibility for outside social contacts, spent nearly all his time with other boys of his own age. The Rorschach tests indicated in the case of twin L the "constriction typical of pre-puberty," although to a less degree in relation to his surroundings than toward his inner life. The personality divergence, as measured by the test, was mainly a matter of difference in the "tempo of development."[12]

In the case of X and Y, one of the pairs of monozygotic boy twins studied by the present writer, an interesting phenomenon presented itself. Both twins were "incubator" babies. Y (the smaller of the pair) weighed four pounds at birth, and X five pounds. The mother developed an over-protective attitude towards Y, who was slightly handicapped by deafness. The "tempo of development" was curiously uneven in the case of X and Y. At the age of eleven, Y was unable to read or write or to "hold his own" in grade school, while X was able to proceed along normal academic lines. X was aggressively friendly outside the home, while Y showed a marked tendency to retreat into a world of phantasy.

The results of the Rorschach test administered in a child guidance clinic when X and Y were thirteen years old showed marked discrepancies in emotional adjustment. At the clinic, X was definitely more cooperative than Y, who "camouflaged" to the best of his not inconsiderable ability in this respect. On the basis of the tests, Y was adjudged to be slightly superior in regard to abstract thinking, while X was regarded as definitely superior to Y by the grade school authorities. The competition between X and Y for the affection of the mother was intense. Removed temporarily from the over-protective home atmosphere, Y responded gradually to the educational program outlined by the clinic, while X, who remained at

[9] *Ibid.*, p. 501.
[10] *Ibid.*, p. 500
[11] *Ibid.*, p. 517.
[12] *Ibid.*, p. 519.

home with his older sibling, gradually abandoned his former hostile attitude towards Y, which had occasioned considerable anxiety in the home.

One of the most ambitious of the recent studies of monozygotic twins is the work of Rosanoff, Hardy and Plesset, who assembled the records of 1016 pairs of twins from child guidance clinics, correctional institutions, medical centers, state hospitals, and prisons. This work covered a period of ten years.[13] The authors analyzed 409 cases of "twins with child behavior difficulties, juvenile delinquency, or adult criminality."[14] Among the monozygotic twins, there were "concordant findings" in regard to delinquency or criminality in 86.9 percent of the cases examined and "discordant findings" in 13.1 percent. Since nearly all the monozygotic twins were raised together, the percentage of "concordant findings" fails to establish the thesis maintained by Lange, Stumpfl and others that a study of monozygotic twins with criminal records "proves" that there is a positive correlation between crime and heredity. Futhermore, even among the monozygotic twins where the "criminal findings" were "concordant," there were "quantitative and qualitative intrapair dissimilarities."

As a study of the etiology of delinquency, crime, and behavior difficulties, Rosanoff's study of monozygotic and dizygotic twins leaves much to be desired because of the fragmentary nature of the case histories assembled by him and his associates. Consider, for example, the history of Wendell and Donald C. These twins were born in 1907. They were adjudged to be monozygotic. The family was "highly respected in the community," the father being a practicing physician. Donald, the first born of the twins, was heavier by one pound at the time of birth. At school he was usually one year ahead of his twin brother. While Donald never "presented any behavior difficulty, delinquency or criminality,"[15] his twin brother gambled, drank to excess, and occasionally used marihuana. At the age of 23 Wendell was arrested on charges of "grand theft and forgery." Released on probation after a term of imprisonment and placed in charge of his family, his later career is unknown. While this case history reveals almost complete divergence of behavior patterns in a pair of presumably monozygotic twins, it sheds little light on the "etiology" of behavior problems. In general, Rosanoff's material fails to substantiate his preliminary statement (considerably modified in his "Summary") that his "findings were roughly in harmony with those previously reported by Lange, Stumpfl and others, as suggesting that *hereditary factors play a part in the etiology of the behavior difficulties under consideration.*"[16]

An analysis of the recent studies of monozygotic and dizygotic twins suggests the following conclusions:

(1) The "twin method of study" provides an ideal set-up for investi-

[13] Rosanoff, A. J., Handy, L. M. and Rosanoff, I. A., "Etiology of Epilepsy, with Special Reference to its Occurrence in Twins," *Arch. Neurol. Psychiat.*, Chicago, 1934, 31, 1165-1193. Also, "The Etiology of Mental Deficiency with Special Reference to its Occurrence in Twins." *Psychol. Monographs*, 1937, 48, No. 4.

[14] Rosanoff, Handy, and Rosanoff-Plesset, "The Etiology of Child Behavior Difficulties, Juvenile Delinquency and Adult Criminality with Special Reference to their Occurrence in Twins." *Psychiatric Monographs*, No. 1., State of California Dept. of Institutions, Jan. 1941, p. 182.

[15] Rosanoff *et al.*, "The Etiology of Child Behavior Difficulties," p. 47.

[16] *Ibid.*, p. 9. (Italics those of Rosanoff et al.) Cf. Stumpfl, F. *Die Ursprunge des Verbrechens, dargestallt am Lebenslauf von Zwillingen.* Leipzig, 1936.

gating the relative powers of "nature and nurture" *only* if used with sufficient scientific precision. However, many published studies have lacked this qualification and have merely supported preconceived notions of the importance of heredity or of environment.

(2) The role played by heredity has *not* been proved in behavior problems, delinquency, or crime, but there is a high degree of probability that certain organic diseases such as schizophrenia *may* be hereditary. In this latter field of study outstanding work has been done by Franz J. Kallmann in recent years.[17] It can scarcely be denied that impressive evidence has been presented by Kallmann and Rudin which would seem to indicate an inherited predisposition for schizophrenia and this evidence is corroborated by such case studies of monozygotic twins as that of Gardner and Stephens.[18]

(3) Even in this area, however, much scientific caution must be observed, while genetic "fatalism" is completely out of place. The *caveat* of Kallmann himself is of special significance. As he accurately observes:

"We may either render the given morbid gene less penetrant, or we may change its expression through carefully directed management of *vital environmental influences* or by methodological mobilization of constitutional resistance factors."[19]

(4) While no sociologist should adopt what F. J. Kallmann calls the "simple device" of denying the role played by human heredity, the importance of family environment is revealed in all careful studies of monozygotic twins.

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[17] Kallmann, F. J., *The Genetics of Schizophrenia*, J. J. Augustin, New York, 1938. See also, *Am. J. Psychiat.* 103: 3. 1946, Kallmann, F. J. and Barrera, *Am. J. Psychiat.* 98: 4. 1942.

[18] Gardner, E. J. and Stephens, F. E., Schizophrenia in Monozygotic Twins," *Journal of Heredity*, 40, p. 165. June, 1949.

[19] Kallmann, F. J. "Applicability of Modern Genetic Concepts in the Management of Schizophrenia," *Journal of Heredity*, 39, Nov. 1948, p. 344. Italics those of present writer.

THE NEED FOR CORPORATE RESEARCH IN THE SOCIAL SCIENCES

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Since the term *corporate research* is not one in general use, I shall define it at the outset. Corporate research is research carried on by a number of individuals representing different fields of specialization (or different disciplines), whose activities are integrated in terms of a general plan, are guided by a recognized leader or director, and are focused upon a single problem or complex of related problems. Although the term *corporate research* may be unfamiliar, the principle is not new. A striking example of the effectiveness of corporate research in the physical sciences is afforded by the work of the Manhattan Project in developing the atomic bomb. One reason the Manhattan Project could be set up quickly and could function smoothly was that the pattern for this type of research organization had already been worked out in the research laboratories maintained by corporations such as General Electric and A. T. & T., and many top-ranking scientists had already had experience with such organizations. Examples of the beginnings of corporate research in the social sciences are found in the work of certain foundations, notably the Russell Sage Foundation, the Scripps Foundation, and the Twentieth Century Fund, and in some of the work carried on by the Bureau of Agricultural Economics of the U. S. Department of Agriculture, also the Food and Agriculture Organization of United Nations.

Corporate research is differentiated sharply from *individual research* —the prevailing form of social research today—in which the individual selects his problem, formulates his hypothesis, determines methods of investigation, gathers his data, and writes up his findings, hoping of course for publication and perhaps professional advancement. Indeed, there are grounds for suspecting that a large part of the individual research now being done in the social sciences is motivated by this hope rather than by an insatiable thirst for knowledge. Consider, for example, how many academic persons find that their thirst has been permanently slaked after their Ph.D. dissertation has been accepted! The shortcomings of individual research were indicated recently by Professor Harold W. Saunders, in reporting on a census of sociological research in Midwestern colleges and universities, when he declared that "most of the research is still highly *individualized endeavor*, carried on as subsidiary to the function of teaching, is short run and piecemeal in organization, and is poorly financed, if financed at all, by funds specifically allocated for that purpose."[1]

Professor Philip M. Hauser, writing at a time when it seemed likely that basic social science research would be provided for by Congress under a National Science Founda-

[1] "The Status of Research in the Midwest Sociological Society," *The Mid-West Sociologist*, v. 12, No. 2, pp. 15-16 (Spring, 1950).

tion, asks the question, "Are the Social Sciences Ready?" and gives a qualified negative answer when he declares that "new research perspectives are badly needed—perspectives not restricted to projects forced into the molds of the spotty and limited financial support of the past." He goes on to express the hope that "adequate financial resources will increase the necessity for, and should increase greatly the number of studies made by competent groups rather than by individual investigators."[2]

Corporate research should not be confused with *joint research*, nor even with *cooperative research* in the usual sense of the latter term. Joint research in science is the equivalent of the *partnership* in business. It is the situation where two or more individual workers, usually representing the same discipline and often the same field of specialization, pool their efforts and results. The type of project undertaken by joint researchers is generally little different from the individual research project, and while the scope of investigation may be broadened considerably and the amount of data amassed may be more imposing, joint research nevertheless has most of the characteristics, and limitations, of individual research.

All scientific research is cooperative in the sense that every investigator makes use of and builds upon the work of others. In the narrower sense in which the term is ordinarily used, however, cooperative research denotes a certain loose cooperation between individuals or institutions (especially the latter) involving, among other things, exchange of information about projects being worked on, conferences on methodology, mutual exchanges of personnel, and in some cases a pooling of data. An example of cooperative research in which data are pooled would be a series of parallel surveys undertaken in different communities by different investigators, but employing a common schedule so that data collected will be more or less comparable. If joint research is comparable to the business partnership, cooperative research may be compared to the trade association in its looser forms. This is not to disparage cooperative research, or cooperation in research. There is need for much more cooperation than now exists in the social sciences and it is not contended that the development of corporate research would reduce the need for cooperation in research. *Social Science Abstracts*, which perished during the depression and which certainly should be revived, was a cooperative enterprise involving interdisciplinary and inter-institutional cooperation in reporting research.

Carrying to its logical conclusion the scheme of analogy we have used in comparing joint research to the business partnership, and cooperative research to the trade association, we may say that corporate research is just what its name implies—the application of the principles of corporate organization to scientific research. As implied in the definition at the beginning of this paper, it involves (1) division of labor, as distinguished from parallel effort, (2) maximum utilization of specialized training and talent, (3) interdisciplinary team work, (4) integration of effort under leadership, and (5) a research plan providing for continuity of effort and the focusing

[2] "Are the Social Sciences Ready?" *American Sociological Review*, V. 11, pp. 381, 382 (Aug. 1946).

of diverse viewpoints upon a single problem or problem complex. Though not implied in our original definition, and not essential to the basic concept, it is important to note also that corporate research, like the business corporation, may make possible a better utilization of available economic resources and also bring to the support of scientific research larger aggregates of capital than are likely to be made available to the less organized forms of research.

1. *Division of labor.* — Adam Smith, in *Wealth of Nations,* pointed out that in his time (c. 1776) it was not uncommon for an English "factory" to consist simply of a warehouse in which a number of skilled workers pursued parallel enterprises, each one performing all the successive operations involved in converting raw material to finished products, and that the output of such a factory was simply the sum of the individual outputs. But he went on to show that a transition was in progress, and that in one industry, the manufacture of the common pin, the manufacturing process had been broken down into separate and successive operations, with the use of teams of workmen in which each worker performed only a single operation; and he pointed out that, as a result of this division of labor, a team of workers was able to produce several times as much as the sum of the outputs of a similar number of workers working as individuals. In the twentieth century, the advantages of division of labor in industry are universally accepted, but scientific research with few exceptions has not yet reached even the stage of the warehouse "factory." It reposes in a still earlier stage—that of cottage industry and the individual craftsman!

In defense of this analogy, it is asserted that industry and scientific research have many essential things in common. Each calls for the exercise of a variety of highly developed skills, each involves well defined processes which can be broken down into concurrent and successive operations in which specialization leads to greater skill and efficiency, and each makes use of tools (or instruments) and stands to gain from that sort of organization in which the worker does not waste time in putting down one tool and groping for another. The universe of scientific knowledge, like that of technical skills, has expanded to the point where no one person can hope to master more than a small segment, yet nations and individuals are daily confronted with problems which call for the concerted, and integrated application of many fields of scientific knowledge.

Imagine, if you can, the plight of a person desiring a modern automobile who is obliged to procure all the necessary raw materials, then seek out workmen with all the necessary skills, then transport his materials from shop to shop until all the parts are finished, and finally assemble the parts himself. Yet such, precisely, is the plight of the man, or the nation, which seeks scientific guidance in the solution of any of the complex problems which we designate by the term "social."

2. *Maximum utilization of specialized training and talent,* as indicated above, is attained only in a situation where tasks are allotted according to special skill and ability and the whole process is so organized as to avoid duplication of effort, but at the same time insure that all needed operations are performed in proper sequence. Anyone who has

had even superficial contact with research in the social sciences must be aware of enormous duplication of effort. If not, a perusal of some of the annual lists of doctoral dissertations in the social sciences is recommended. Even at the level of advanced research, universities and individual scientists compete openly with each other in the exploration of certain favored fields, and turn a deaf ear to proposals for division of the field and the sharing of results, doubtless for the unspoken reason that to do so would involve sacrifice of institutional or individual credit and prestige, though the shibboleth of freedom of scientific investigation is likely to be advanced as public justification of their disinterest, if justification is demanded.

But duplication of effort is not the only loss we sustain because of our highly atomized and individualized research. Because choice of research problem is largely a matter of personal bent (or institutional bias), research tends to be spotty and discontinuous, so that when one surveys the field of social phenomena as a whole, he finds certain areas mapped and plotted in great detail—even trivial or useless detail. These are the popular areas, the areas of research toward which attention runs.

For example, in sociology, family relations, juvenile delinquency, social disorganization (a rather vague and formless concept), and recently, race or minority group relations have been strong favorites. But at the same time there are vast areas of *terra incognita*. Some of these areas, such as religious behavior and sex behavior, are fenced off by institutional bars. A certain amount of peripheral exploration is permitted, provided it is done delicately and reverently, but one must not go into the dark woods, and one must be careful not to step on the flowers or frighten the little rabbits.

On the other hand, there are large and important areas which are neglected for no discernable reason save that nobody seems to be interested in them. For example, sociology has largely neglected the study of popular music and other forms of popular art; and while sociologists have studied intensively certain aspects of criminology, the study of law-making, law-observance, and law-enforcement as social processes has been neglected. Social workers and sociologists have long been concerned with the effects of poorly balanced diets, but sociological literature contains only a few small and scattered studies dealing with the relationship of food habits to other aspects of culture such as intergroup prejudice and social status. Here is certainly a problem for interdisciplinary teamwork with dietitians, physiologists, psychologists, and sociologists all playing on the team.

It is not contended that corporate research will solve all problems of mal-distribution of research effort, but like the Scandinavian gentleman's daily ration of sixty-four cups of coffee, "it will help." It will help in four ways: (1) Corporate organization of research will certainly reduce the amount of needless duplication of research. This point seems so obvious that space will not be taken to argue it. (2) Confronting barriers of prejudice or tabu, an organized group with respected institutional backing can make a stronger attack, with less individual risk than can the lone researcher. (3) With respect to the neglected areas in the research map, it may reasonably be assumed that interdisciplinary team-

work will help. Bringing together investigators trained in different fields means that more questions will be asked and the searchlight of science will be played over a larger area. (4) A research team on which different but mutually supporting fields of specialization are represented will be able, not only to see more aspects of a central problem, but to pursue more related lines of inquiry and hence avoid the errors of particularism which have appeared so often in the social sciences.

3. *Interdisciplinary teamwork.*—In the preceding section we have already pointed out how interdisciplinary teamwork can contribute to the more effective utilization of specialized training and talent and lead to a broader concept of problems and more comprehensive investigations. Interdisciplinary teamwork appears to offer one answer to the dilemma of *specialization versus understanding,* i.e. a means whereby the social sciences can supply, not only the minutely detailed knowledge of the specialist, but also broad understandings which can come only from knowledge which is both intensive and extensive, and which are so necessary in the processes of prediction and planning.

For example, to understand and deal effectively with intergroup relations—racial, ethnic, religious, or economic—calls for a team in which anthropology, economics, psychology, and sociology are represented, because that complex social phenomenon which we call *prejudice* is far more than a pre-judgment or fallacious belief which can be speedily vanquished by giving people the facts. It is a witches' brew, compounded of folk myths and superstition, religious convictions, economic interests, sentiments of group loyalty, vague fears and anxieties, displaced hostilities, and frustrations, with added special ingredients according to the particular brand of prejudice. Nothing could be more futile and absurd than trying to deal with so complex a phenomenon as if it were a simple matter of interpersonal understanding which can be cleared up by getting the facts in the open and bringing the parties together so that they can shake hands.

4. *Integration of effort under leadership.*—Anyone who has ever had the experience of working on, or with, a faculty committee knows that even scientifically trained minds, without leadership, have a disconcerting tendency to "ride off furiously in all directions" and spend a precious afternoon in getting nowhere at all. Corporate research involves, as an essential element, the existence of acknowledged leadership and the willingness of all persons engaged in such research to respond to leadership. This does not mean mechanical control nor the sacrifice of what we ordinarily understand as intellectual freedom and integrity. In the staff conference ideas and proposals may be batted around the circle without regard to the rank or seniority of their authors, but in the end, if there is to be an end, someone must be able to fuse divergent proposals together into a plan acceptable to all. And when divergence becomes so sharp that this is not possible, there must be someone, commanding the respect of all, to make a decision. Admittedly this involves risk, and some compromising of freedom, but so does marriage, or signing a contract, or entering into any significant social relationship.

This seems particularly applicable to research carried on by graduate students in our universities. Working individually and guided only by occasional conferences with busy professors, they turn out each year scores of theses and dissertations containing vast accumulations of painfully collected data which the student has analyzed mechanically, by methods learned the previous semester. Problems selected are often inconsequential, or so narrowly defined as to be of little significance unless supported by related studies; and the interpretation of findings is halting, confused, and lacking of insight. Surely the minds and energies of these young people could be utilized better if they were assigned to work for a semester, or a year, with an organized group under skilled leadership, instead of being forced to strike out on their own.

5. *A research plan.*—Stressing the need for more and better planning in social science research, Professor Hauser insists that

> we must regard it as a basic obligation, to plan social science research projects that meet the requirements of good design of experiment. This does not mean that all research projects must be put into a test tube or brought into a laboratory, or that all research projects must be quantified. It does mean, however, that all important variables involved in a given problem should be brought under "control". It does mean that steps should be taken to assure that the population studied is a representative population—representative of the entire universe from which it is drawn or a selected segment of that universe which can be rigorously described. It does mean that the study should be set up in a manner to permit generalizations and conclusions whether they be of a positive or negative nature. Too many researchers in the past have, largely because of limited resources, stopped where they really should have begun—at the point where qualitative or quantitative studies have provided initial insights into the problem under exploration. Exploratory case studies or statistical studies will, of course, still be necessary, but adequate resources should result in projects which follow through—in carefully designed studies in which the variables are known and controlled and which result in statements of social laws and probabilities.[3]

The essence of a research plan is to be found in the concept of continuity—logical continuity and temporal continuity. Research should have logical continuity in the sense that it covers completely a defined area of investigation and maintains scientific liaison with related areas; it should have temporal continuity in the sense that it builds upon the validated results of earlier research and at the same time provides leads for future investigation and further validation. There are at least five requirements for a sound research plan.

To begin with, a research plan must be built around a defined problem, or problem complex. A problem may be defined in terms of a specified category of social phenomena, for example, competition or assimilation, in which case it is usually designated as a *theoretical* problem; or it may be defined in terms of a specified institution or institutional pattern, for example, marriage, education, or a specified group or population, in which case we designate it as a *practical* problem. As the social sciences have operated until now, the emphasis upon the practical type of problem has been much stronger than in the case of the theoretical, and there is probably little reason to suppose that this situation will change, nor to wish that it should change, for the soundest structure of theory is often that which is built up in the process of finding solutions to practical problems. The important thing is that the problem, whether "practical" or

[3] *Ibid.*, p. 382.

"theoretical," shall be so defined as to include all ramifications and permutations. In other words, the great sin of research planning is oversimplification of the problem.

A second requirement of good research planning is the collation of all existing research data which have a bearing on the problem, in order that unnecessary repetition may be avoided, and the investigation may be so ordered that it will add to present knowledge. The importance of this is obvious, but the means of doing it, so far as the social sciences are concerned, are not obvious. Because of the individualistic and unorganized character of social science research in the past, and in the absence of classified lists and cross-indexes of published research data, it is virtually impossible for a social scientist today to know what has been done, or even what currently is being done with respect to a certain problem.

Having defined the problem and taken account of all existing knowledge which bears upon it, the third step in research planning is to formulate a series of hypotheses which shall, as far as possible, cover all solutions to the problem which are logically conceivable in the light of existing knowledge, and this leads directly to the fourth step, which is the designing of an experiment (using that term in its broadest sense), or a related series of experiments, which shall test, not one, but all of the hypotheses. Good experimental design, as Hauser has indicated, means setting up a plan of inquiry in such a way that when the inquiry is completed, the various hypotheses will either be "proved" or "disproved." A conclusion which falls short of this is really no conclusion at all.

Finally, in the sound plan of research, there must be an analysis of the task and a determination of the personnel needs. What disciplines and what fields of specialization within disciplines need to be represented in this study? When this has been done, the plan may be said to be complete; there remains only the administrative (and perhaps financial) problem of finding suitable staff and organizing them into a research team.

For most institutions now engaged in social science research, corporate research must be regarded as a goal to be approached gradually rather than as a procedure to be adopted immediately. One obvious reason for this is the problem of financial support. Large-scale, comprehensive research projects of the sort described here call for research budgets seldom dreamed of in the social sciences. Moreover, they call for an entirely different sort of grant from that which foundations and research councils are accustomed to make. The practice which has developed and become strongly entrenched in the social sciences is for available research funds to be parcelled out in small grants ($500 to $3,000) to individuals on the basis of competitive "bids." If progress is to be made in the development of corporate research, institutions and foundations must be educated to the point where they recognize that the structure of knowledge cannot be economically built by the same principles which govern the erection of a new wing on the gymnasium.

Yet one of the reasons for the niggardly support now given to research in the social sciences undoubtedly is to be found in the present shortcomings of social science research. In other words, *if the social*

scientists could do better research, they could get more money, and if they had more money, they could do better research. How is this circle to be broken? As indicated above, it cannot be done all at once, but I think it can be done. The first steps must, obviously, be taken by the social sciences themselves. Specifically, the following measures are suggested:

1. Organization of interdepartmental discussion groups or faculty seminars to promote a broader approach to social problems and lay the foundations for interdisciplinary teamwork.
2. Establishment of social science research committees or councils charged with the function of developing broad, coordinated research programs. Such groups already exist in many universities, but their usual function is adminstration rather than planning — they consider the "bids" of individual researchers and parcel out research funds or research time on an individual basis, making sure that no department gets more than its share.
3. Progressive integration of individual research efforts, including the "forced" research of graduate students, into a broad plan that is focused upon a locally or nationally significant problem complex.

The possibilities of action along these lines can be illustrated by an account of what we are doing at Southern Illinois University. For a long time, southern Illinois has been regarded as a problem area, but we at the University have come to regard it as an area of unrealized opportunity. From the standpoint of research, it is a veritable sociological laboratory, since it is culturally an interstitial area where the distinctive culture traits of northern and southern regions meet, intermingle, and not infrequently "slug it out." We have not yet been able to accomplish the first two steps outlined above, but within the Department of Sociology we have developed a long-range research plan which is based upon the corporate concept of research, have secured limited financial support from the University for this plan, and have hopes of getting foundation support. With a small budget provided by the University, we are collecting and collating presently available information about the area. We have been reasonably successful in persuading graduate students to work on research problems which fit into our plan, and in building up the staff of the department we constantly keep in mind the requirements of a well-balanced research team, which we find is not necessarily incompatible with the equally important objective of developing an effective *teaching* team.

In conclusion, I turn to a problem which I am sure has been troubling many during this discussion—the problem of possible dangers in corporate research. Will it destroy intellectual freedom and lead to regimentation of investigation, followed by regimentation of thinking? In answer to this question, I wish to assert, first of all, that there are vital differences between *integration* and *regimentation.* Indeed, it may well be argued that the survival of free society depends upon our discovering practical means of achieving integration of effort without regimentation.

In the second place, it is far from my intent to advocate corporate re-

search to the exclusion of individual research. There should always be a place for the investigator of rare talents who can perform a brilliant piece of research by himself, as well as for the unorthodox theorist whose hypotheses may seem insane to organized research agencies.

In the third place, while I have emphasized the adaptability of corporate research to large-scale projects, I am not blind to the dangers of cartelized research. I can, for example, foresee the possibility that a National Research Foundation, financed by Federal appropriation, might lead to a dangerous degree of cartelization, and I think the exclusion of social sciences from the benefits of the pending legislation may some day be viewed as a fortunate thing. The social sciences need scores of well-organized research teams, based on the campuses of our leading colleges and universities, and financed from many sources—local contributions, state or municipal appropriations, foundation grants, and even Federal grants where they can be obtained without sacrifice of local control or self-sufficiency. And all this, I must insist, is compatible with the concept of corporate research.

ZOOLOGY

THE USE OF HORSE STRONGYLE LARVAE IN SCREENING COMPOUNDS FOR ANTHELMINTIC ACTIVITY

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Since the discovery of the sulfonamides, research in chemotherapy has gone on at an ever-increasing rate. One phase of this expansion has been an intensification of the search for new and better anthelmintics.

The pattern of this type of research is essentially that which was used during World War II in searching for new antimalarial and antifilarial drugs (cf. Wiselogle, 1946, and Conference on the Chemotherapy of Filariasis, 1948). Hundreds and even thousands of compounds, selected more or less at random, are tested for activity. When a promising compound is found, other related compounds are synthesized and studied.

Because so many compounds are studied in the initial screening test, a rapid, cheap technic is essential. The host which one wishes to treat is usually unsatisfactory because it is too large, too expensive to maintain, or not available in sufficient numbers. Hence workers have turned to *in vitro* tests or *in vivo* tests in small laboratory animals.

Neither of these types of test is completely satisfactory. Both miss compounds which would be effective against parasites of economic importance; both give promising results with compounds which are later found to be valueless against these parasites. Brackett and Bliznick (1949), for instance, using *Nippostrongylus muris* in the mouse (*Mus musculus*), screened over 1625 compounds for anthelmintic activity. Among the known nematocides which they tested, carbon tetrachloride was fairly active, but tetrachlorethylene, hexylresorcinol, and phenothiazine were not satisfactory. Santonin and beta-naphthol were practically worthless; gentian violet, thymol, and n-butyl chloride were completely ineffective. On the other hand, trichloracetamide and some of its relatives were highly effective. Unfortunately, this compound turned out to be ineffective against *Strongyloides ratti* in the rat (*Rattus norvegicus*), *Syphacia obvelata*, *Aspicularis tetraptera*, and the adults and larvae of *Trichinella spiralis* in the mouse (*Mus musculus*), and *Litosomoides carinii* in the cotton rat (*Sigmodon hispidus*).

In the last analysis, if one wants to find a compound which is effective against a particular parasite in a particular host, he must test it against that parasite in that host. No other procedure will give definitive results. The screening tests simply help in the hunt.

In vitro tests are usually faster and cheaper than *in vivo* ones. It is not necessary to have facilities for

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housing and handling many experimental animals, and the tests can be done conveniently on a table top. On the other hand, the results obtained in an *in vitro* test cannot necessarily be carried over without modification to the living animal. The drug-helminth reaction is a relatively simple, clear-cut one *in vitro*, but introduction of a host into the reaction brings in many modifying factors. A compound which is active *in vitro* may not be active *in vivo*, and *vice versa*. And an effective compound might turn out to be too toxic for the host to be used.

In vitro tests can be carried out either on the adult worm or on larvae. The advantage of using the adult is that it is the stage for which animals are treated. The metabolism of the larva often differs from that of the adult, so that a drug which kills larvae might not kill adults, and *vice versa*. Nevertheless, larvae are often so easy to obtain and to use that screening with them is justified. Otto and Maren (1948, 1949), for instance, discovered the new antifilarial compound, arsenamide, as a result of screening with *Dirofilaria immitis* larvae.

The screening test which I shall describe is a modification of the test developed by Parnell (1936). It uses the larvae of horse strongyles as test organisms. These nematodes belong to the family Strongylidae. Dikmans (1945) lists three species of large strongyles (genus *Strongylus*) and 36 species of small strongyles of 11 different genera as occurring in horses and other equids in North America. Practically all horses have multiple infestations. It does not seem to matter a great deal which species is used in the test.

The eggs of these nematodes are passed in the feces. First-stage larvae hatch in about a day, feed in the manure, and molt to long-tailed second-stage larvae in another day. These also feed in the manure. In a few days they molt again to become short-tailed third-stage larvae. The second-stage cuticle is not completely cast, but is retained as a protective sheath around the third-stage larvae. These larvae do not feed. They leave the manure, crawl onto the vegetation, and are eaten by horses when they graze.

This test was originally designed to be used in searching for compounds which would kill the larvae on pasture. However, it is also applicable to screening drugs to be used against the adults.

Strictly speaking, this is not an *in vitro* test, since it is carried out against larvae in their natural environment. However, since no host is involved, the test is generally grouped with the *in vitro* tests.

The chemical compound to be tested is mixed with talcum powder to give it body. One-half gram of this mixture is mixed thoroughly with 4.5 g. of fresh horse manure containing strongyle eggs. The manure-talc-chemical mixture is placed in a small cheesecloth bag, which is suspended in a closed, 2-oz. wide-mouth glass jar. The jar is set aside in a dark cupboard for a week. By this time the larvae have reached the third stage, and many of them have migrated out of the feces. They collect in the droplets of condensation water which appear on the sides of the jar, and can be recognized by examining the condensation water with a powerful hand-lens (I use a 15-X microscope ocular).

If no larvae can be found, the bag is placed in a Baermann apparatus (a funnel with a piece of rubber tubing closed by a pinch-clamp).

Enough warm water is poured into the funnel to half cover the bag. If larvae are present, they migrate into the water. After an hour or two some of the water is withdrawn through the rubber tubing at the bottom of the funnel, and examined for larvae with a low-power microscope or hand-lens.

The presence of living larvae indicates that the compound was ineffective. In the work cited above, both Parnell and I counted the larvae, but I now feel that this is not necessary in a screening test of this type.

In the preliminary screening test, each compound is set up in concentrations of 0.01, 0.005, 0.0025 and 0.001 M. If these give promising results, further studies are carried out. In my earlier work, I used standard percentages of compounds, but comparisons on an equimolar basis are preferable.

Untreated controls are essential, since in an occasional manure sample the larvae failed to develop.

One advantage of using talcum powder as a diluent instead of attempting to dissolve the compounds is that both soluble and insoluble compounds can be studied without changing the technic. In addition, a compound whose solubility is not known can be screened without taking time to determine if it is soluble.

Because of the nature of this technic, it is impossible to tell whether a compound acts on the eggs or on the first-, second-, or third-stage larvae. This does not affect the value of the test for screening purposes. For more precise information, the effect on each stage could be determined separately.

The selection of a manure donor is important. A strongyle egg count of at least 1000 eggs per gram of feces is desirable. Horses will sometimes be found in whose manure larvae do not develop well; such horses cannot be used as donors.

So far over 150 compounds have been screened against horse strongyle larvae. The results on 70 have already been reported (Levine, 1949), and those on the others will be reported later. A number of promising compounds have been found, including several iodine compounds.

Among known nematocides which were tested, 1% sodium fluoride, nicotine sulfate, and phenothiazine killed all larvae in the manure, while 1% hexylresorcinol killed 99.5% (compared with the number of larvae present in the controls). When present in a concentration of 0.1% in the manure, crystal violet killed 53% of the larvae; hexylresorcinol, 79%; phenothiazine, 82%; sodium fluoride, 84%; and nicotine sulfate killed them all. This last compound killed 99 to 100% of the larvae in four tests at a concentration of 0.01%.

Summary

A cheap, convenient technic is described for screening chemical compounds for possible anthelmintic value, using horse strongyle larvae as test organisms. The compound to be tested is mixed with horse manure containing strongyle eggs. The mixture is suspended in a cheesecloth bag in a glass jar. The jar is set aside in a cupboard for a week, and the jar and manure are then examined for larvae.

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A COMPARATIVE STUDY OF NORMAL AND PIEBALD HAMSTERS*

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A coat-color mutation in the golden hamster *(Cricetus auratus)* was recently described (Foote, 1949). Preliminary studies of this mutant strain, designated piebald because of the white coloring about the face and eyes, suggest that there are variations from normal associated with the coat-color change. Keeler (1947a, 1947b) has indicated that certain coat-color genes manifest themselves in all parts of the mammalian organism by producing modifications of morphology, physiological nature, and behavior. In this piebald strain of hamsters the first morphological difference observed, other than coat color, was that these animals appeared smaller and their body weights were less than those of normal animals. A preliminary study of this weight difference has been reported (Foote and Bullock, 1949).

This report brings together some of the data accumulated during the past two years in comparing the piebald strain of hamsters with normals. Studies described here are for body weights, litter size and mortality, and reproductive tract abnormalities. Coat color for the mutant strain will be described and sex distribution discussed.

Results

Coat color.—The animals of the hamster colony used in this study were graded on the basis of coat color. The normal coat coloring for this species of hamster is light brown on the back and white on the underside, with a brown band across the chest between the forelegs. White areas extend from the fronts of the forelegs and from the throat region up and forward across the cheek pouches (fig. 2). An animal with coat color of this kind was graded as P-0.

The first noticeable variation from normal toward piebaldness is the appearance of a strip of white in the center of and at right angles to the brown band between the forelegs. This area of white becomes wider as animals tend more toward the piebald condition until the brown area is entirely absent. Animals showing variations in the degree of white on the chest were graded P-1 to P-5 (fig. 2). The animals graded P-5 have no brown color on the underside and are completely white on belly, chest, and throat. Animals in grades P-1 to P-5 show the normal brown color on the back.

Animals graded P-6 to P-10 show varying degrees of white on the nose, face, and back, and lack all brown color on the underside (fig. 3). Young animals will show the piebald color pattern as soon as they become pigmented after birth, on about the third day, and the pattern is never varied as the animal becomes older.

In the present paper the hamsters in grades P-0 to P-2 (344 ani-

* Aided by grants from the General Research Fund, Southern Illinois University.
† With the technical assistance of Charles B. Koch.

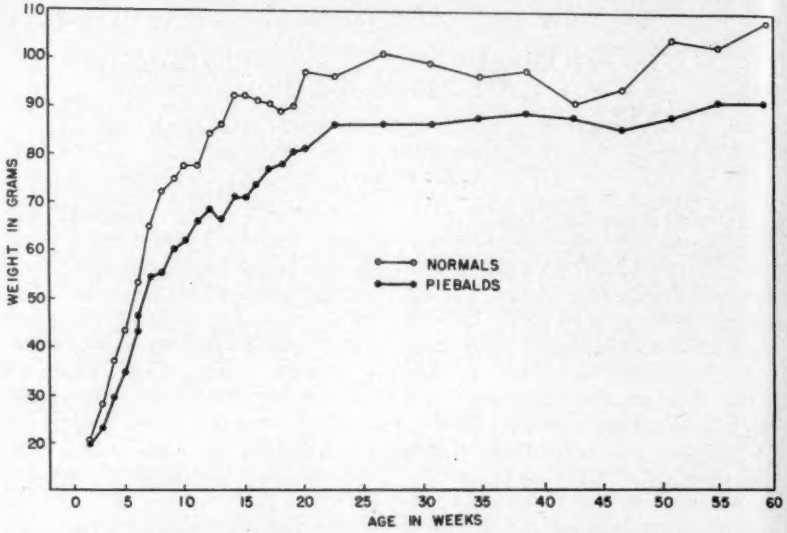

FIG. 1.—Comparison of mean body weights of normal and piebald hamsters. Points up to 23 weeks plotted by weeks; points after 23 weeks plotted by months.

TABLE 1.—SEX DISTRIBUTION

	P-0	P-1	P-2	P-3	P-4	P-5	P-6	P-7	P-8	P-9	P-10	
Females	72	62	36	9	16	9	6	7	9	4	8	238
Males	71	81	22	10	12	7	12	5	8	1	10	239
Total	143	143	58	19	28	16	18	12	17	5	18	477

mals) are considered to be normals, while those in grades P-3 to P-10 (133 animals) are considered piebalds.

Sex distribution.—In the total colony of 477 animals the sexes were almost equally divided, 238 females and 239 males. Distribution by sex and grade is given in table 1.

Body weight.—The first observed variation from normal in the piebald animals, other than coat color, was in body weight. It appeared that they were somewhat smaller and weighed less than normals.

Body weights were taken weekly for a period of 58 weeks on a Hanson Dietetic Scale, on Friday afternoon of each week, before the animals had been fed for that day. All animals were fed the same diet of leaf lettuce, laboratory chow, and milk. Weights of most animals were taken from the time they were 16 days old, the time of weaning. The total number of animals weighed each week varied somewhat since they were being used in other studies and some had to be sacrificed.

Normal animals showed a consis-

FIG. 2.—Undersides of normal and piebald female hamsters showing varying grades of piebaldness. Female on upper left is P-0; female on lower right is P-10.

FIG. 3.—Backs of same animals as in fig. 2. All are in same relative positions in both photographs.

TABLE 2.—BODY WEIGHTS
Mean weights in grams

Age in Weeks	Normal males		Piebald males		Normal females		Piebald females	
	No. Wts.	Mean Wt.	No. Wts.	Mean Wt.	No. Wts.	Mean Wt.	No. Wts.	Mean Wt.
2.....	27	20.48	13	20.69	13	17.77	12	17.50
3.....	27	27.59	28	22.82	17	25.59	21	20.05
4.....	38	37.74	37	28.27	45	35.38	28	27.71
5.....	46	45.39	46	35.28	47	39.02	30	33.33
6.....	31	52.77	49	44.72	35	52.43	27	44.93
7.....	26	64.39	52	53.60	36	64.00	29	53.69
8.....	36	71.50	45	56.01	44	70.95	32	53.84
9.....	33	72.36	53	59.84	27	73.30	40	58.30
10.....	30	76.43	50	62.72	17	76.65	26	61.00
11.....	22	78.90	36	63.88	13	80.07	20	66.50
12.....	20	81.50	28	66.07	13	87.07	17	68.82
13.....	13	80.92	19	65.31	10	90.10	16	65.81
14.....	11	85.54	9	70.44	8	99.00	10	72.81
15.....	14	86.21	16	68.00	9	98.33	13	72.84
16.....	10	80.50	15	73.06	8	99.62	10	71.80
17.....	4	86.75	11	78.81	3	92.33	8	73.12
18.....	12	81.25	15	74.60	8	96.25	10	74.70
19.....	4	87.50	14	77.23	2	90.50	6	84.66
20.....	7	91.57	13	79.46	3	97.00	6	82.50
21-60.....	114	98.05	235	84.70	50	92.45	118	89.38

tently heavier body weight than did piebald animals (fig. 1), as indicated by mean weekly weights of total number of normal animals compared to mean weekly weights of total number of piebald animals. The difference in the mean weights of the two groups for the period of 58 weeks was 12.13 grams. The greater body weight of normals becomes apparent when the animals are about 3 weeks old and the difference in weight between normals and piebalds gradually increases until they reach the age of 14 to 15 weeks. Apparently it is at the approximate age of 15 weeks that the hamster begins to reach its adult weight, since from that time on no great increase in weight is evident.

The weight difference between piebalds and normals remains more or less constant after the animals reach their adult weights. While the weight attained at 20 weeks remains somewhat stable, the piebald and normal females show little weight difference as adults. The weight difference between normals and piebalds is accounted for by the weights of the males of the two groups (table 2). Of the 4 groups of hamsters, normal males, normal females, piebald males, and piebald females, the normal males are heaviest while piebald males weigh the least.

Litter sizes and litter mortality.—In the hamster fewer young are born to piebald mothers than to normal mothers. When litters are produced from matings of normal males with normal females the litters are larger (mean litter size of 6.69), and more of the young survive (4.81). If either or both parents are piebald there are fewer young in a litter (4.76), and the mortality of the young is higher (2.72 surviving). Litter size and mortality are given in table 3.

TABLE 3.—LITTER SIZE AND LITTER MORTALITY

	No. of Litters	Total Young Born	Young per Litter Born	Young per Litter Surviving	Total Young Surviving	Percent Young Surviving
Normal male X Normal female	62	415	6.69	4.81	300	72.29
Normal male X Piebald female	8	50	6.25	3.50	50	56.00
Normal female X Piebald male	35	191	5.46	3.63	127	66.49
Piebald male X Piebald female	50	202	4.04	1.96	98	48.52
Normal female X Piebald male Normal male X Piebald female Piebald female X Piebald male	93	443	4.76	2.72	253	57.12
Normal male X Piebald female Normal female X Piebald male	43	241	5.60	3.14	135	56.01
Entire Colony	155	858	5.54	3.57	553	64.44

The young from piebald parents are smaller and weaker than normal young and as a result the mother animals, whether normal or piebald, are prone to destroy them. In addition to this factor, piebald mothers are more nervous and do not care for their young as well as normal mothers. The young of piebald mothers are more likely to starve and die from neglect.

Reproductive tract abnormalities.—In piebald animals a condition of either partial or total sterility may exist, especially in females. No detailed study has been made of the cause of sterility in the male piebald animals, but in the case of one male, graded P-10, who was mated numerous times to both piebald and normal females, no young were born. Cases of non-fertile matings are more common among piebald animals than in normals. Such non-fertile matings may be due to a condition of sterility in the male, the female, or both.

In a group of 42 piebald females that were sacrificed the reproductive tracts of 7 were abnormal. Among normal females, one with an abnormal reproductive tract was found in a total of 165 females sacrificed. The abnormalities observed were in the horns of the uteri. Of the 7 piebald females with abnormal tracts, 4 had no left uterine horn, one had a right uterine horn missing, and one had no uterine horns. In one instance the right horn was absent, but the left horn had been pulled across the body cavity and attached near the right ovary. Two of the 7 females had no left kidneys. In the normal female the left uterine horn was absent. In all of these cases the ovaries, fallopian tubes, and lower portions of the reproductive tracts appeared intact.

All females with reproductive

tract abnormalities had at some time been in estrus, exhibited the usual sexual behavior, and had copulated. Each had mated at least twice and some as many as 6 times. In only one case were young known to have been born and that female had a record of four matings, three of which had been non-fertile. After the fourth mating she gave birth to a single animal. After the mother animal had been sacrificed it was found that she had only one uterine horn, the right.

The investigation of these reproductive tract abnormalities is incomplete and more detailed study is in progress.

Discussion

Coat-color changes in hamsters (*Cricetus auratus*) similar to the one described in this paper have occurred in other hamster colonies in this country. Dr. Margaret Ward Orsini, in a recent personal communication, stated that piebald animals which appeared in her colony and were then inbred for several generations, developed a greater degree of whiteness than have these animals in the colony here. Hayner (1949) reported a white-faced hamster mutant appearing among the animals in his hamstery. As far as is known no studies of the genetics of this piebald mutation in the hamster have appeared in the literature.

Data presented in this paper suggest that there are certain morphological variations and possible differences in maternal behavior between piebald and normal hamsters which may be related to the coat-color modification of the piebald animals. Keeler (1947a) has advanced the hypothesis that such differences, in many mammalian forms, are due to a relationship between a mutant coat-color gene and its correlated modifications of morphology, physiology, and behavior. Even though results obtained from these studies of the piebald mutant suggest that there is such a relationship, no definite statement should be made until the genetics of this strain of hamsters is more fully understood and other studies completed.

Results presented here for the normal hamster vary little from those reported by Bond (1945). Body weights of normal animals in this colony show a slightly higher mean body weight up to the time the animals are 100 days of age. After that age the weights are approximately the same as those given by Bond, with normal males being heavier than normal females.

Bond found that the mean litter size in her colony was 6.93, as compared to a mean litter size of 6.69 reported here.

Summary

1. Normal hamsters (grades P-0 to P-2) show a greater body weight than do piebald hamsters (grades P-3 to P-10).

2. The sex ratio is 1:1 among normal and piebald animals.

3. Normal hamsters have larger litters than do piebald hamsters, and more young survive in litters produced by normal animals.

4. Reproductive tract abnormalities occur more frequently in piebald females.

5. The differences in morphology and behavior of piebald hamsters may have a relationship to the mutant gene or genes producing the coat-color change.

6. Those animals considered

normals in this study have body weights and young per litter similar to those given for a different hamster colony.

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PROBLEMS IN THE BIONOMICS OF THE SQUASH BUG, *ANASA TRISTIS* (DeGEER) (COREIDAE, HEMIPTERA)

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Although numerous articles have been published on the squash bug, the bulk of the material concerns methods of control, and many questions in the area of its bionomics have either remained untouched or received insufficient consideration. The squash bug has several characteristics that favor it for observation and experimentation: (1) it is large —about 5/8 inch in length; (2) it is common; (3) the sexes are readily distinguished; (4) all the stages are passed in full view above ground and can be reared in captivity; and (5) while capable of flight, the adults tend to remain on foot if food is adequate and the temperature moderate. In view of its suitability for research, a brief summary of its essential bionomics is desirable.

The squash bug appears to confine its feeding to members of the family Cucurbitaceae, favoring certain varieties of squash and pumpkin. The coppery brown eggs are attached in loose groups to the underside of leaves, and the five instars of greyish nymphs and the brown adults appear on foliage and vines during the growing season. When frost kills the leaves, both nymphs and adults may accumulate, sometimes in large numbers, on the cucurbit fruits left in garden or field after harvest. The nymphs, while small, tend to remain congregated about the site of the eggs, but they become isolated as they grow larger. Only the unmated adults live through the winter, sheltered under rubbish, boards, stone piles, and similar cover. In the northern states, the wintered adults return to cucurbits in June, mate and deposit eggs largely in June and July. The nymphs grow through their five stages from midsummer to October, the old adults die by the late summer and the number of new adults increases from July to October. In this latitude and northward, there appears to be only one generation a year. The eggs are subject to attack by minute endoparasitic Hymenoptera of the families Scelionidae and Encyrtidae while the larva of a tachinid fly, *Trichopoda pennipes* Fabr., inhabits and destroys both the adults and nymphs (Beard).

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Notes on Problems

Sex ratio.—While observing the behavior of confined squash bugs, Girault found that males mated repeatedly and with different females. From this polygamy, he inferred that the males are numerically inferior to the females. However, this inference is shown by the data cited below to be incorrect. In his study in Connecticut, Beard collected 1000 adults in August and September, 1935, which "showed 449 males and 501 females, indicating that the newly matured bugs have a sex ratio of .5. . . . Tabulations made during June and July, 1936, of 1430 overwintered bugs, gathered at random

Table 1.—Lengths and Sex Ratios of *Anasa tristis*

TABLE 1.—LENGTHS AND SEX RATIOS OF *Anasa tristis*

Date of Collection	Length in Millimeters						Total Bugs Collected	Males		Females	
	Males			Females							
	Number Measured	Extreme Lengths	Average Lengths	Number Measured	Extreme Lengths	Average Lengths		Number Collected	Percent	Number Collected	Percent
October 6.....	74	12.4 15.2	13.65	76	13.0 16.6	15.36	992	494	49.80	498	50.20
October 8.....	77	12.0 14.8	13.36	78	13.7 16.5	15.00	995	561	56.38	434	43.62
October 9.....	50	12.3 14.5	13.22	49	13.3 16.3	14.80	781	383	49.04	398	50.96
October 10.....	118	11.6 14.7	13.34	114	13.3 16.5	14.83	2,007	1,061	52.86	946	47.14
October 13.....	99	11.5 15.0	13.05	100	13.1 15.3	14.46	1,284	658	51.25	626	48.75
October 15.....	32	12.0 13.4	12.71	34	13.2 16.0	14.47	66	32	48.48	34	51.52
October 21.....	73	11.2 13.6	12.54	87	12.5 15.3	13.94	164	73	44.51	91	55.49
October 28.....	18	10.8 13.0	12.23	25	12.6 15.7	13.93	43	18	41.86	25	58.14
November 6....	3	12.8 13.0	12.93	4	13.5 14.7	14.07	7	3	42.86	4	57.14
Totals.....	544			567			6,339	3,283	51.79	3,056	48.21

in the field, included 653 males and 677 females, the difference being of no significance as tested by the Chi-square."

In the fall of 1942, I discovered a fine population of nymphs and adults in a one-eighth acre of squash and pumpkin at Urbana, and used it to secure data on the relative numbers of the sexes. Nine separate collections were made, at times stated in the accompanying table, in the period October 6 to November 6. The numbers taken per day do not represent the total bugs then present, but reflect merely the intensity and duration of the periodic searches. However, all but a very few of the individuals that constituted the population were, I believe, secured by November 6. And because the bugs showed no inclination to fly when pursued, no significant part of the population was omitted through emigration, nor the number present supplemented significantly, if at all, by immigration from other areas. Only the obviously more mature dark-brown adults were taken on any date, to avoid prejudicing the measuring of lengths by the inclusion of smaller, newly molted unfed individuals.

The daily lots were assembled alive in a ventilated half-gallon fruit jar, the cover having a hole just large enough to receive a bug inserted lengthwise, in order to prevent escape. After asphyxiation in ether, the individuals were segregated as to sex and a sample of each sex measured. The ventro-caudal area of the male abdomen is transversely convex and entire, excepting a small median genital "button," while that of the female tends to be flat and is subdivided into small genital sclerites.

Reference to the table will reveal that 51.79 percent of the 6339 bugs that made up the collections were males and 48.21 percent were females. It seems likely that each sex would be found to constitute 50 percent of the population or species if much larger samples were taken over a succession of years and from a number of separate fields. The variations in the percentages of males and females taken on the 9 dates are probably to be attributed to chance, and do not indicate an actual or normal fluctuation in numerical preponderance of one sex over the other. Moreover, Beard found no evidence to indicate a differential mortality that alters the 50-50 ratio of the sexes throughout the year.

The females of this sample exceeded the males in length of body by 1.39 mm. The 567 females measured averaged 14.53 mm., the 544 males averaged 13.14 mm. in length. The largest female measured 16.6 mm., the smallest 12.5, while the largest male had a length of 15.2 mm., the smallest 10.8 mm. Moreover, the size of both males and females lessened perceptibly and somewhat gradually as the period of collecting progressed. Since nymphs were always purposely left in the field in order to permit them to become adults, it is probable that the later collections contained a high proportion of newly transformed adults. And because late-maturing individuals were obliged to feed on the old fruits, the leaves and vines having been killed by frost early in October, the phenomenon of diminishing size appears to reflect an inadequacy of food. Also the progressive shortening of the days and lowering of temperatures as October progressed may have contributed to this reduction.

The life cycle. — Gould, Beard,

Worthley, and Weed and Conradi report one generation in a year in Indiana, Connecticut, Massachusetts, and New Hampshire, respectively. By inference, some writers suppose the squash bug completes one cycle annually also in other northern states, but this point needs to be checked by studies in the field. Moreover, this bug has two generations per year in Missouri (Haseman) and three in southern Kansas (Wadley), and may produce even more cycles still farther south. Such additional cycles, are, it appears, commonly presumed to result from the higher average temperatures prevailing at more southerly latitudes. However, these supernumerary cycles may be even more directly associated with the long occurrence of succulent growing cucurbit tissues that is made possible by the protracted warm period.

Diapause.—New adult squash bugs develop as early as July in the northern states. Although they exist at temperatures favorable to reproduction from July to September, they are known not to mate and produce eggs until the subsequent summer. Such failure to advance the life cycle at summer temperatures is a characteristic of diapause. The problem here concerns the identity of the presumed non-climatic factor that inhibits sexual activity in July-September, and limits the squash bug to one generation in the north. Some studies on diapausing insects point to the low water content of drying or aging plants as the diapause-producing factor. It is said to lower the water content in the insect. This suggests that nymphs and adults fed only on succulent seedling cucurbits may not be subject to a diapause. Simple laboratory tests embodying this suggestion can probably be easily carried out.

How cucurbits are injured.—Being equipped with piercing-sucking mouthparts, *Anasa tristis* removes sap from its food plants. However, such mechanical removal of sap, in itself, seems inadequate to explain the sometimes extensive wilting, searing, and dying of cucurbit crops. Various writers have called attention to this wilting, and Robinson and Richards (1930, 1931) state from their investigations that the wilt, for which they propose the name "*Anasa* wilt of cucurbits," is not caused by any parasitic form of bacterium, fungus, or virus. These and other observers suggest that the wilting results from a toxic substance injected by the bug while feeding. If so, the toxin is probably contained in the saliva, or salivary glands, and quantities of it might be analyzed by modern microchemical techniques and also injected artificially into potted, disease-free cucurbits to note whether it produces the symptoms of wilt as it occurs in the field. If the results prove to be positive, the substance might be injected into non-cucurbit plants to note whether it has the power to produce wilt in these also.

Why the preference for cucurbits?—The fact that the squash bug chooses cucurbits over numerous other plants present in its environment, and moreover, prefers certain varieties of squash and pumpkin over other species and varieties of the family, indicates it is capable of making fine distinctions, presumably through a keen sense of smell residing in the antennae or proboscis. This predilection also raises the question whether cucurbits contain a certain combination of nutrients

essential to the growth and reproduction of the squash bug. Two experiments are indicated above. First, to find what organ is the seat of selective sense. Second, to find whether the squash bug can be induced to feed on non-cucurbit plants, e.g. soybeans or corn grown in pots, when such plants are sprayed with extracts or decoctions from favored varieties of squash and pumpkin. If nymphs can be reared and adults maintained on such plants, it would be of interest further to note the effects on size, vigor, rate of growth, and capacity for reproduction. It is conceivable that the species might fare better on some non-cucurbits than on the preferred varieties of its chosen family of food plants.

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ECOLOGICAL NOTES ON *THANATOPHILUS AMERICANA* L.

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Thanatophilus americana L. is a carrion beetle of the family *Silphidae,* tribe *Silphini,* and subgenus *Oiceoptoma* Leach. This species is broadly oval and, like the rest of its tribe, strongly depressed. It is about five-eighths of an inch long. The prothorax is yellow with a central black area, and the rest of the body is black or brownish black. Blackburn (1936) describes the morphology of this beetle in detail, including the sexual dimorphism of the apices of the elytra. The campodeiform larvae are entirely black, very active, have an amazing capacity for food, are cannibalistic when food is scarce. The larvae of *T. americana* and related species have been described by Dorsey (1940).

T. americana has some advantages as the subject of field and laboratory studies. First, it is abundant in season and can be easily collected in baited traps. Second, the adults brought in from the field will live for long periods of time under suitable laboratory conditions. Third, the adults will lay eggs in the laboratory, the eggs can be hatched, and the young raised to the imago stage. Finally, Purina Lab Chow can be substituted for decaying meat as a diet for the beetle, thus eliminating offensive odors. The disadvantages are chiefly these: *T. americana* cannot be collected, at least in large numbers, except by rather smelly traps; it is available only during the warmer months; it is a large beetle and thus experiments with large numbers require much space.

In spite of these disadvantages, however, *T. americana* seems to be well adapted to certain types of laboratory work. This paper is intended to introduce *T. americana* to scientific society as a laboratory animal of sorts. Although the collecting of this beetle still involves malodorous bait, the odor is mitigated by fresh, outdoor air. And since the objectionable odors of decaying flesh have been eliminated from the process of maintaining this beetle in the laboratory, *T. americana's* debut may be moderately successful.

Collecting Methods

Cans sunken into the ground and baited with meat have probably been used from time immemorial for traps. But open cans are subject to the depredations of local carnivores, bait lying loose in the can quickly becomes messy, and rainwater may drown the trapped beetles. Certain precautions will avoid these mishaps. Cans with tight-fitting covers should be selected, preferably gallon paint cans, since the covers can be pried off easily after the cans have been sunk into the ground. A cross-shaped slit should be cut into the lid and the free ends of the triangles thus formed bent slightly inward. The jagged edges thus formed effectively prevent any purloining of the bait but do not interfere with the entry of the beetles. The bait should

be wrapped in gauze, tied with a string, and suspended from a heavy wire bar fastened across the diameter of the can near the top. If the bait is suspended with a bent paper clip, it can be taken out of the trap easily while the catch is being removed. Finally, the can should be located so that rainwater will not drain into it and a sizable hole left under it into which water can drain from holes punched through the bottom of the can. When these precautions are observed, ground traps prove to be very successful. The disadvantages are chiefly the immobility of the traps and the inconvenience of removing the beetles with the hand or long forceps.

More elaborate hanging traps can be constructed which eliminate the necessity of digging holes in the ground, and which can easily be moved from place to place. This provides for easy renewal of the bait, and the beetles can be removed merely by screwing off a glass jar and dumping them into a container. A plan for such a trap has been published by the Chicago Museum of Natural History. A modification of this trap was constructed by a local sheet metal shop in Quincy. Wide-mouth, self-sealing fruit jars were used. The center of the cap is discarded, leaving a metal ring which will screw onto either a quart or pint jar. The metal rims were soldered to a galvanized metal funnel. Three baffles were soldered to the funnel and screwed to a conical metal roof. A wire cloth capsule for the bait can be inserted easily into the central area of the baffles. This trap has been quite successful. A study of the relative efficiency of the ground and hanging traps and the effect of height will be undertaken during the coming summer.

Decaying fish has been used very successfully in the past as a bait in both ground and hanging traps, but there is a tendency for the bait to dry instead of putrifying in the hanging traps. Plans for testing chemical attractants are being made, since a constant lure would be invaluable in field studies. Dethier (1947) mentions some attractants for the *Nicrophorini* but none for the *Silphini*, except those generally attracting this type of insect.

Habitat

In the Quincy area, *T. americana* has been trapped in sparsely wooded, humid bottomland and along upland streams in wooded areas which remain moist during the summer. In this area, however, it is impossible to study habitats of flying insects accurately by trapping, since open fields, scantily wooded areas, and dense woods are interspersed and no type of habitat is very extensive.

During July 1947, eighteen days of trapping in the Chicago area yielded interesting results. Traps were placed in a parkland area near a stagnant pond, in oak forest, and in prairie. In the dunes area several traps were scattered through the black oak, cottonwoods, and foredunes. Each of these areas was very extensive, covering many square miles. Thus the catch gives some indication of the species present. The parkland traps yielded 460 *T. americana*, the prairie traps only one pair, and the traps in the oak forest one single specimen. *T. americana* was not found in the dunes area. These collections seem to indicate that *T. americana* is a parkland species, inhabiting open woods or semi-denuded areas where

water is available. It is absent from other environments, at least during the summer. At Quincy it has been collected from similar areas.

T. laponica was the only species present on the prairie in numbers and thus seems to be a prairie species, having been collected from no other area. It has not been taken in the Quincy area, a fact in favor of its being a native of the prairie. *T. inaequalis* was abundant in the forest of oak on upland areas and showed up in the black oak forest in the dunes area. *T. noveboracensis* was not notably abundant anywhere, but 27 specimens were taken in forest traps. Observations indicate that this species breeds early in spring. Recently, April 15, 1950, breeding individuals were observed on a carcass in upland woods, and shortly afterwards hundreds of larvae appeared. In the spring of 1947 traps were visited almost daily from April 8 to May 29. *T. americana* appeared later than the other species and was not taken at all or only in small numbers when the night temperature fell below about 50°F. Seasonal studies might show an interesting avoidance of competition between these species in terms of habitats and breeding seasons.

Husbandry

Laboratory observations and experiments have indicated the needs of *T. americana* for survival under domestication. Adult beetles will live for long periods of time in any type of container if provided with food and water. The bottom of the container should be covered with absorbent paper or soil. Water may be furnished in small glass dishes. Pieces of gauze or paper should be placed in the dishes so that the beetles can escape drowning by climbing out after falling or crawling into the dishes. Meat (cooked or raw), fish, and Purina Lab Chow have been used successfully for food. For life history studies, paired adults may be kept in wide-mouth fruit jars and covered with the original caps in which screen has been substituted for the removable center. Moist soil, water, and food must be provided. The lack of any of these items will stop egg production. The eggs are deposited in the moist soil in cavities excavated as the beetles burrow through the soil. The necessity of using moist soil usually excludes sifting for the eggs since most available soils do not sift well when moist. The eggs can be recovered by searching through the soil with brush and section lifter.

The eggs are large and cream-colored and enclosed in a pliable but tough outer cover. They will hatch successfully if placed in petri dishes on moist pieces of paper towel. The eggs quickly swell to about twice the size of a newly laid egg. If they are not kept moist they quickly dry and shrivel up. In this connection it is interesting to note that the adult beetles will not oviposit in dry soil, as shown by an experiment involving about four dozen pairs of *T. americana*. All of 409 eggs, laid over a period of two weeks, were laid in moist soil, although dry soil was equally available and convenient.

The larvae can also be maintained in petri dishes, but a wad of wet gauze to supply water and food must be added. During the third instar the larvae eat for the first few days and then become extremely restless unless placed in a container of moist soil where they hollow out a cell within which they pupate. The soil must be kept moist in order to insure suc-

cessful pupation and ecdysis. This latter point has the support of experimental evidence. Of a total of 56 third instar larvae which were ready to construct their earthen cell, 27 were placed in moist containers and 29 in dry containers. Of the 27 in moist containers, 24 pupated, 21 reached the adult stage. Of the 29 individuals placed in dry containers, 6 pupated and 2 reached the adult stage. Thus 77.8% pupated successfully in moist containers and only 6.9% in dry containers.

Life Cycle

The eggs hatch in from one to four days, the mean time necessary being about three and a half days. The time spent in the first instar varies from less than one day to about three and a half days. The mean time is slightly less than two days. The second instar is very similar in length to the first. The third instar is the longest stage in the development of this beetle. It varies in length from about 8 days to 14 days, the mean being about 11 days. The third instar larvae are very active for a few days, feeding and then constructing their earthen cell. A few days after the cell is complete, they turn over on their backs and become immobile, except for twitching the abdomen. The pupal stage varies in length from 8 to 13 days, the mean time required being about 8 days. The pupae are extremely sensitive to light and mechanical stimulation of any kind. Towards the end of the pupal stage they are less sensitive but still react easily to slight jarring and strong light. Hence it is difficult to examine them closely while alive. The pupae are almost pure white at first but soon develop a light brown coloration on spines, appendages, and peripheral areas. The adult beetles are very light in color at first. The elytra are a semi-transparent white whereas the body is a light brown. Full coloration is developed after two or three days. The mean length of time from egg to adult is about 26 days and varies from 25 to 27. These studies of the life cycle were carried out at a constant temperature of 25°C. They will be described in greater detail in another paper.

Discussion

The study of the complete ecology of *T. americana* and its relatives promises to reveal interesting interspecific adjustments. *T. americana* and probably also other species can be used in the laboratory for the study of the effect of temperature and food on the rate of development. Since this beetle will eat and do well on an artificial diet its nutritional requirements can be studied in detail. The adults are not overly sensitive to handling and thus make good subjects for behavior studies. Exploratory work along this latter line has been done. It must be said, however, that the usefulness of *T. americana* as a laboratory animal is still to be proved.

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THE OCCURRENCE OF *ENTEROBIUS VERMICULARIS* OVA IN DUST FROM HOMES AND PUBLIC BUILDINGS

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In recent studies, a theory has been proposed concerning the occurrence of ova of the pinworm *Enterobius vermicularis* in household dust. Lentze (1935) showed that eggs were liberated into the air when sheets and clothing contaminated with them were shaken, and suggested that the ova might be inhaled to produce infection. In studies by Noland and Reardon (1939) (see table 1) and Schuffner and Swellengrebel (1944), ova were found in dust at all levels of rooms examined, on the floor, upholstery, light fixtures, and on the moulding of doors and windows. The conclusion drawn from their experiments was that viable ova may be present in the air throughout an infected household and that the possibility of reinfection by inhalation of the ova must be considered in prophylaxis and in the therapy of individuals in such households. Our investigation was made to check further this possibility and to ascertain the occurrence of *Enterobius vermicularis* ova in the dust of institutions and homes in the Bloomington-Normal, Illinois, area.

In the study by Noland and Reardon (1939) of the incidence of *Enterobius vermicularis* in persons residing in or near Washington, D. C., the method of procedure consisted of collecting dust samples from various parts of the houses studied and subsequent microscopic examination. Pinworm ova were demonstrated in 221 of 241 samples studied (91.7 percent). Schuffner and Swellengrebel (1944) found enormous quantities of pinworm eggs on two-meter high window seats of school lavatories, in schoolrooms and in dining rooms where children stayed only for short periods.

In the work here reported 3 households and 24 public buildings were examined (see table 2). The 3 homes consisted of families with children. Two of them were not clean according to cleanliness standards. In the third home, the entire family was being treated for pinworm infection. Twenty-two samples of dust were obtained from these homes. Of the three samples of dust from the home where infection was known to be present, two positive findings were obtained. The 19 samples from the other two homes were all negative. A 9.09 percent positive finding resulted from examination of the 22 dust samples from the three homes.

The public institutions examined included: 8 schools, 2 orphanages, a children's ward in a hospital, 3 theaters, 4 hotels, 2 cafes, and 4 other public buildings. A total of 149 samples of dust were obtained from these buildings. Of these, 101 were from the orphanages. Only samples taken from the dormitories and restrooms of the orphanages gave positive results. An 8.1 percent positive finding for public institutions and a 11.8 percent positive

TABLE 1.—COMPARISON OF INCIDENCE OF *Enterobius vermicularis* OVA IN HOUSEHOLD DUST OF WASHINGTON, D. C., AND BLOOMINGTON-NORMAL, ILLINOIS, AREA.

	Washington, D. C. (Nolan & Reardon)	Bloomington-Normal Illinois Area
No. of Homes	7	3
Households of Known Infection	7	1
No. of Samples	241	22
No. of Positives	221	2
Percent of Positives	91%	9.09%

finding for Bloomington-Normal orphanages was obtained.

Most samples from the three homes and the two orphanages were taken from bedrooms or dormitories. A few were taken from the toilet rooms. Samples were taken from all levels of the rooms, especially the framework of beds and places where linen and bed clothing were shaken out, and where night clothing and undergarments were located. In the toilet rooms, dust samples were taken from seats, ledges around the toilet, and the floor. It seems significant that ova were found in only one instance near the floor. They were usually found at levels of from two to five feet from the floor.

Two methods of dust sampling and study were employed: (a) the deep-well slide method as described by Noland and Reardon, and (b) the scotch-tape method as used by Schuffner and Swellengrebel for anal smears. The deep-well method consisted of the collection of dust samples with a small camel's hair brush which had been inserted into a perforated rubber stopper and fitted into a test tube. The brush was moistened with water, passed over a surface, replaced in the test tube, and brought back to the laboratory for examination. The examination consisted of dipping the brush into a few minums of decinormal sodium hydroxide solution

TABLE 2.—THE INCIDENCE OF *Enterobius vermicularis* OVA IN DUST OF PUBLIC BUILDINGS IN BLOOMINGTON-NORMAL, ILLINOIS, AREA.

Public Buildings	Areas Studied	No. of Samples	No. of Positives	Percent
1. Schools	Cloak Rooms Rest Rooms Halls	23	0	0
2. Hospitals	Childrens Ward	8	0	0
3. Orphanages	Dormitories Toilet Rooms	101	12	11.8
4. Theaters	Auditorium Rest Rooms	3	0	0
5. Other Public Buildings	Conjested Areas	14	0	0
Total		149	12	8.1

on a deep-well slide and study of contents under a compound microscope. The ova having a lower density than that of the decinormal sodium hydroxide solution tended to float to the top. A few drops of the solution placed at the hilt of the brush and allowed to flow across it on to the slide seemed to be most effective as a means of cleansing the brush of the dust deposits. Each dust sample was examined three times. No attempt was made to determine the total number of ova present in any sample. In the scotch-tape method, a one and one-half inch strip of tape was placed over a surface and then carefully transferred to a clean slide. The slide was then examined under a compound microscope for ova.

Enterobius vermicularis ova were found in all stages of development from those of clear formative protoplasm with many vacuoles to full-grown embryos. Many of the embryos were in a partially disintegrated condition and their viability questionable. The eggs were clear and plain and were easily identified without staining. They measured from 50 to 60 microns by 20 to 30 microns and in general, were flat on one side with a distinct membranous covering.

The evidence from this study indicates that ova of the internal parasite, *Enterobius vermicularis,* are carried by air currents and may be inhaled, and thus be a source of infection and reinfection.

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THE INCIDENCE OF *ENDAMOEBA GINGIVALIS* IN A CENTRAL ILLINOIS COMMUNITY

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It was believed at one time that *Endamoeba gingivalis* was the causative organism of, or at least associated with, the condition known as pyorrhea. With the work of Dobell (1919), Craig (1926), and others who denied this claim, the organism has more recently been given a position of less importance as an etiologic factor in oral cavity disease. Investigators have repeatedly observed this protozoan in the mouths of humans, particularly at the base of the teeth. The present study was made on a group of dental patients (1) to supply further data relative to the occurrence of this organism in man and (2) to note further its relationship to different conditions of oral hygiene in persons of varying age levels.

According to Kofoid (1929) at least 75 percent of persons over forty harbor the organism *Endamoeba gingivalis*. The incidence of this organism found by L. W. Ritchie (1932) in the Chicago area ran as high as 80 percent in older age groups. Samples for the present study were obtained from 110 patients with the cooperation of a practicing dentist[1] in the city of Bloomington. Of the 110 samples examined, the following percentages of infection were obtained: Adults, 41.8 percent; teen-age, 11.1 percent; and children, 13.3 percent. The incidence of *Endamoeba gingivalis* in different types of mouths was: 100 percent in pyorrhea mouths, 78.3 percent in dirty mouths,[2] and 25.8 percent in mouths that showed evidence of good daily oral hygiene. The dentist was supplied with sterile cotton swabs, and scrapings were taken from the spaces between the teeth, around the region of the gum, and pyorrhetic absesses. The condition of the mouth was classified as clean, dirty, or pyorrhetic. The patients were divided further into child, teen-age, and adult groups. Since the examination of the scrapings could not always be undertaken immediately, the swabs were placed in small vials containing 1½ cc. of 0.85 percent physiological saline solution. To insure against change of temperature the vials were kept in an incubator at body temperature. In most cases examinations were made from 3 to 24 hours after the specimens were collected. Most active forms of the organism were found when the examination was made within 12 hours after the sample was obtained. In one instance a very active organism was found after the specimen had been in the incubator for 72 hours.

In the microscopic examination of the samples, oil immersion was used. The slides as well as the cover slips were placed in the incubator to prevent sudden shock due to changes of temperature. The swabs were taken from the vials and smeared on slides.

The size of active organisms var-

[1] We are indebted to Dr. D. L. Winquist for his cooperation in providing us with samples for study.

[2] Mouths which indicated poor daily oral hygienic care—decaying food particles between teeth; yellow film deposits and stains on teeth.

TABLE 1.—INCIDENCE OF *Endamoeba gingivalis* FOUND IN THIS STUDY OF THE BLOOMINGTON, ILLINOIS, AREA AND RITCHIE'S FINDING OF THIS ORGANISM IN CHICAGO, ILLINOIS.

Age Group	No. Exam.	Sex		Pyorrhea	Dirty	Clean	Percentage in Age Group	Age	Ritchie's %
		Male	Pos.	4	6	7		50 and over	83.4
			Neg.	0	2	23			
								41-50	89.9
Adults.....	86	Female	Pos.	1	11	8	41.8	31-40	80.7
			Neg.	0	2	23		21-30	72.8
		Male	Pos.			1			
			Neg.			5			
Teen-age...	9						11.1	16-20	50
		Female	Pos.			0			
			Neg.			3			
		Male	Pos.		1	1			
Children....	15		Neg.		1	5	13.3	5-15	46.5
		Female	Pos.			0			
			Neg.			6			
Percentage in type of mouth.....				100	78.3	25.8			

ied from 12 to 37 microns. The size may double in a matter of minutes and the shape varies constantly, at times being just an amorphous mass. The inactive organisms measured on the average 17 microns.

In appearance the endoplasm is usually crowded with food particles and granular material which seems to float in the center of fluid cavities. The ectoplasm is crystal clear. The pseudopodia are rounded and blister-like and flow out in the direction of movement, at times explosively and at other times very slowly. The granular endoplasm then flows into the transparent area. In active forms bacteria seem to adhere to the side opposite the pseudopodia, but in dead forms this adhesive force is lost. Bacteria were also noticed within the cytoplasm. On the slides containing numerous organisms there were fewer free bacteria present. This gives support to the theory that the organism ingests bacteria. Active forms were fixed in Bouins' solution, stained in haemotoxylin, and permanently mounted.

Table 1 shows percentages of infection found in this study in different types of mouths, age groups, and sex groups with Ritchie's findings listed for comparison. Since the patients studied represent a cross section of the area with respect to occupation as well as economic status, we feel that the data are highly indicative of the incidence of *Endamoeba gingivalis* in the mouths of persons in this central Illinois community.

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A NEW METHOD FOR STAINING CELLS WITH COBALT AND BAL

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Cobaltous ions when used as a mordant form a colorless complex salt with the tissue constituents. The loci of cobalt complexes are rendered visible by developing them to a dark brown with BAL (2-3 mercaptopropanol).* Since a large amount of sulfur is present in the protoplasm and since cobalt has a high affinity for sulfur, we believe that the original complex formed when the tissue is mordanted in cobalt is a cobalt-sulfur complex. Another reason for believing that a cobalt-sulfur complex is formed is that a tissue treated as though prepared for an —SH test renders a better color.[1]

Compounds containing one —SH group do not form any color when cobalt is added unless the pH of the compound is 8.5 or higher. When a compound containing two or more —SH groups is added to cobalt a brown color is immediately obtained. H_2S and cobalt form a black sulfide.

This staining method is very useful for the fibrillar portions of the cytoplasm, especially for the staining of the mitotic spindle and centrioles. We wish to state that this is not a method for testing for the presence of —SH groups.

Fixation of material with trichloroacetic acid, 10 percent; formalin, 10 percent; Bouin's solution; Flemming-Strong solution; Allen's B-15 solution; Allen's B-20 solution; or Zenker's solution gives good results when stained by the cobalt-BAL method.

Blood for staining white cells is fixed in 100 percent alcohol 1 minute, dried quickly in air, and fixed in 10 percent trichloroacetic acid. The hot method of blood fixation by igniting the alcohol does not allow staining.

The procedure in general is as follows:

1. Fix and embed sections, mount material on slides (bleach if necessary with H_2O_2 as in Flemming-Strong technique).
2. Remove paraffin.
3. Hydrate to H_2O.
4. Place in 5 percent Zn $(Ac)_2$ 10 minutes.
5. Rinse 3 minutes.
6. Place in 3 to 5 percent Co $(NO_3)_2$ or any other cobaltous salt from 30 minutes to 12 hours.
7. Wash 1 to 30 minutes in running tap water.
8. Place in 35 percent alcohol containing 0.5 percent 2-3 mercaptopropanol. (*Note*: place the mercaptopropanol into 85 or 95 percent alcohol, then dilute to 35 percent alcohol and 0.5 percent BAL.)
9. Wash, dehydrate, clear, and mount.

If the material is placed alternately into cobalt and BAL, washing in water between cobalt and BAL

* We are indebted to Hynson Wescott and Dunning, Inc., Baltimore, Maryland.

[1] Rapkine nitroprusside test for —SH groups. Techniques of Histo and Cytochemistry, Interscience Press, New York, 1949.

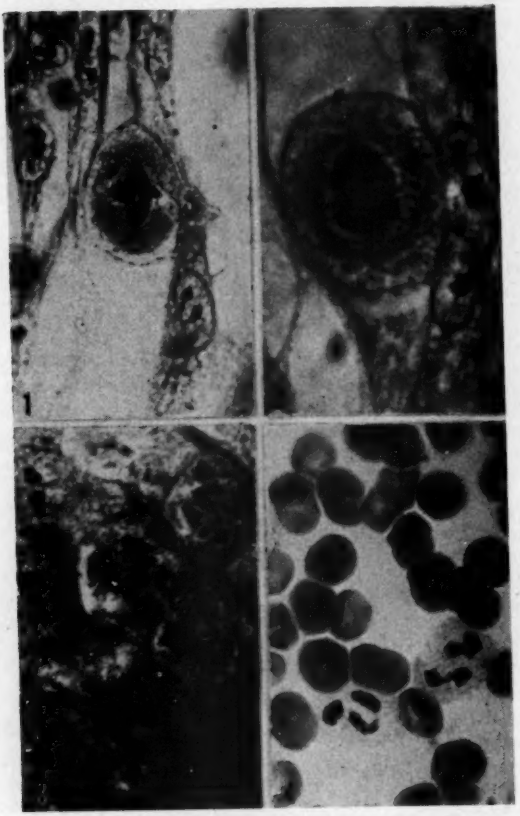

FIG. 1.—Metaphase spindle, tissue culture, chick heart fibroblasts.

FIG. 2.—Late anaphase, tissue culture, chick heart fibroblasts.

FIG. 3.—Late maturation division, grasshopper testis.

FIG. 4.—White cells, human blood.

and BAL and cobalt each time, the stain is strengthened infinitely.

Figures 1-4 are representative of this technique. The pictures were made using a micro-ipso attachment and 35-mm film.

COLLEGIATE SECTION*

THE STUDY OF CICATRIZATION IN PLANT TISSUES

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The purpose of this study was to observe the processes by means of which plants heal their wounds and protect the tissues in the vicinity of such wounds from harmful factors. The comparison was made of such processes in a small herbaceous land plant, *Oxalis,* and the water plant, *Elodea.* The leaves of the said plants were either cut with scissors or pierced with a needle so that the perforation passed entirely through the leaf. Then the operated leaves were cut off and fixed 10 minutes after the operation, 20 minutes, half an hour, one hour, two hours, and so on up to 24 hours, and then one day, two days, three days, and so on. The fixative used was almost exclusively acetic alcohol. However, in some cases the sublimate acetic was also used, as intended preparation to the Feulgen reaction. The stain used was exclusively the Harris Modification of Hematoxylin of Delafield. The leaves of both plants were thin enough to allow the total preparation, especially in the case of *Elodea.* In the case of *Oxalis,* which is less transparent, the method of microtome sections was sometimes used, the sections being prepared from 7 to 15 microns thick. These sections were also stained with Hematoxylin of Delafield, sometimes after sectioning, sometimes previously, staining the leaf in total and then preparing the sections. In all cases the stain was differentiated by means of alcohol acidulated with hydrochloric acid (2 drops per 100 cc.).

Another purpose of this study was to see if some kind of regeneration or new formation would take place at the operated points of the leaves as has been described in some cases, in *Begonia* and some other plants. During these experiments, no regeneration took place either in *Oxalis* or in *Elodea,* the process reducing itself to the formation of a protective layer. This process proved to be completely different in the land plant and in the water plant.

In the land plant, *Oxalis,* from the biological standpoint, showed nothing but rapid dying away of the cells surrounding the wounds owing to the rapid loss of water because the epidermis was destroyed on both sides of the leaf. The cells thus exposed to drying rapidly shrank, the protoplasm condensing while the central vacuole containing the cellular sap, and normally occupying the greater part of the cell, diminished and finally disappeared. The diminishing of protoplasm in volume caused the chlorophyll grains to be brought together and to become concentrated. Then the cell became an irregular body containing the nucleus, which also began to shrink in its central portion, but no process of any kind took place in them. Finally,

* The second paper in the Collegiate Section chosen for publication by the Committee was withdrawn too late for a replacement to be selected.—Editor.

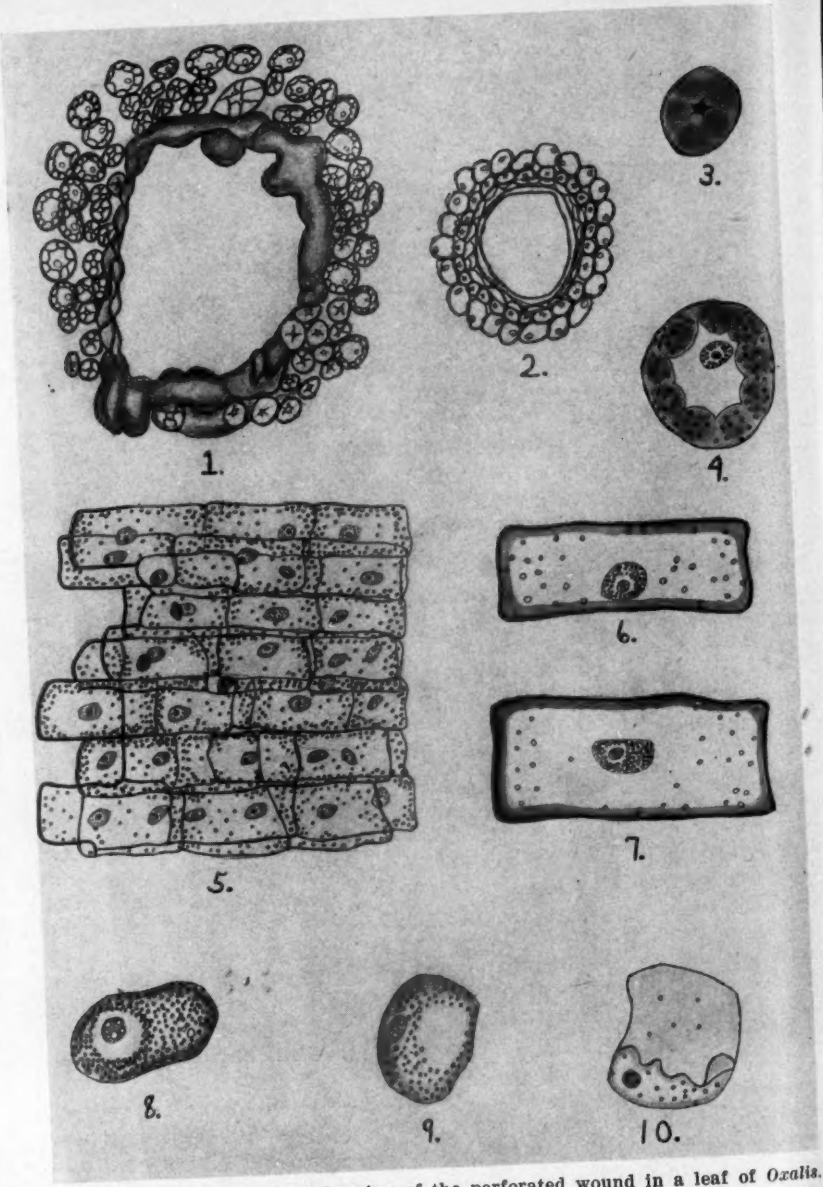

FIG. 1.—Partly schematized drawing of the perforated wound in a leaf of *Oxalis*.
FIG. 2.—Schematized drawing of the preceding.
FIGS. 3. and 4.—Parenchyma cells of Oxalis at different stages of contraction owing to evaporation through the wound.
FIG. 5.—Drawing of a portion of an incised edge of an *Elodea* leaf.
FIG. 6.—Normal cell of *Elodea*.
FIG. 7.—*Elodea* cell with part of membrane thickened because of contact with water.
FIG. 8.—Normal nucleus of parenchyma cell of *Elodea*.
FIG. 9.—Beginning of degeneration of same.
FIG. 10.—Nucleus in advanced stage of degeneration.

the nucleus was completely crushed by the hardening protoplasm and the whole cell became a small irregular clot. The adjacent cells, undergoing a similar change, fused with it and all together formed a continuous layer of substance in which the individual cells could no longer be distinguished. However, for some time the remainder of the nuclei were still seen in stained preparation as irregular granular masses.

This layer of substance, mostly proteic in nature, was nothing but coagulated protoplasm, which also contained cellular walls and therefore was partly cellulose. Then it dried up and formed a hard crust completely covering the surface of the wound. Nevertheless, this protective layer seemed to be not quite adequate to stop the evaporation until it became thick enough. The whole process was very rapid, taking only 10 to 20 minutes. A few days following the operation, the protective layer extended itself over a few more layers of cells which underwent the change described. Here the process stopped, because of the sufficient thickness of the protective layer which prevented the further evaporation of the water.

Figure 1 is a drawing of the wound as it appeared in the leaf of *Oxalis* when pierced with a thin needle. Figure 2 is a schematic representation of the same wound. The first layer of substance which can be seen surrounding the opening is simply a mass of cells crushed by the needle. Outside of this is a layer of cells which died because of the loss of water due to evaporation, and which form a protective layer. Adjacent to the latter layer appear the cells which have already shrunk but still can be distinguished individually. Each nucleus is seen as an irregular stellate body in the center. The outside layer contains living cells not yet affected by the process. The formation of the first protective layer was exceedingly fast, taking place in 10 to 20 minutes; then the only change observed during an interval of time varying from several hours to several days was growth of the layer. No reproduction of the surrounding cells was observed nor any tendency toward the regeneration.

As a conclusion it can be stated that the healing process of the wound in this small herbaceous plant is not biological in nature and cannot be termed as a true cicatrization process because it is simply a physical one consisting of loss of water due to evaporation through the wound, accompanied first by coagulation and then drying up of the protoplasm of the affected cells. However, the fact that these cells fused together allows the formation of a quite adequate protective crust which prevents further evaporation on one hand and on the other gives an adequate protection against the penetration of bacteria and fungi. The only biological phenomenon which takes place is of a necrotic nature. It is a rapid dying away of the cells directly or indirectly affected by the lesion. The extreme rapidity of the formation of the protective layer permits a comparison of it to a certain degree with blood coagulation rather than with cicatrization. However, the elements involved and the nature of the process are entirely different.

A control experiment was carried on by submerging and perforating the plant in water. No formation of a protective layer took place under these conditions, while the exposed cells suffered the process of

gradual disintegration. Therefore, it may be concluded that the principal factor in the formation of the protective layer is the evaporation of water through the wound.

The second part of this work was directed to the study of the same process in a water plant, *Elodea*. The technique was essentially the same. The young leaves of *Elodea* were either cut or prickled and then fixed after regular intervals of time. The fixative and the stain was the same as for *Oxalis*. The process of the wound healing in this case proved to be entirely different than the one observed in the land plant, taking a considerably longer time, and being purely biological in nature and justifying the term "cicatrization." The cells adjoining the wound and exposed to direct contact with water did not die in most cases, but responded to the water stimulus by the thickening of that part of the cell wall which is exposed to such contact. In some cases, as can be seen on the illustrated figures, the cell wall became two or even three times thicker and also stained much more intensely than the ordinary cells. In some cases, it was also observed that the membrane became multilayered. This process of thickening or reinforcement of the membrane implies the local process of secretion, the whole response of the plant in this case being of a purely biological nature. Nevertheless, it must be observed that some cells apparently are unable to respond quickly enough and die away. Then the adjoining cells reinforce their walls and in this way stop the process of destruction. The nuclei of the cells which could not respond become more compact and refringent, later acquiring an irregular outline and finally being destroyed.

MEMORIAL

NEIL EVERETT STEVENS
1887-1949

In the death of Neil E. Stevens on June 26, 1949, at the age of 62, the Illinois State Academy of Science lost a supporter and friend whose interest in our organization was consistent and helpful during his thirteen years of residence in Illinois. Born in Portland, Maine, in 1887, he was educated at Bates College and at Yale University, which awarded him the Ph.D. degree in 1911. His professional career included one year of teaching at Kansas State College, 24 years in the Bureau of Plant Industry of the U. S. Department of Agriculture as plant pathologist, and 13 years at the University of Illinois as Professor of Botany, Head of the Department, and Professor of Plant Pathology in the Department of Horticulture. During his professional career, he was active in a number of scientific organizations, including the American Association for the Advancement of Science, the Botanical Society of America, the Mycological Society of America, and the American Phytopathological Society. He was president of the American Phytopathological Society in 1934 and of the Botanical Society of America in 1947, and served for a number of years on the council of the A.A.A.S.

Professor Stevens' most intensive research centered upon diseases of corn and cranberries, and his publications on these diseases are widely recognized and valued for their high scientific quality and their precise writing. His many-faceted personality and his extensive interests are

reflected in the numerous papers which he wrote on topics other than his major research interests. His friends and students, as well as those who never had the privilege of personal contact with him, will continue to gain mental stimulation and gentle amusement from his papers on the excessive politeness of American botanists, brevity at botanical banquets, scientific fads, bureaucracy as a way of life, the re-education of educators, and fun in research. His scientific interests, although centering upon plant diseases, were not limited to that field, for he published several papers on geology, paleobotany, and the history of American botanists and their works. His total bibliography comprises 176 papers, of which five were published in the Transactions of the Illinois State Academy of Science.

Those who knew Neil Stevens will remember him for his sparkling wit, his intense interest in students and in problems of teaching, his facile pen, his great human sympathies, and his abiding interest in science at all levels, in the high schools and small colleges, as well as in the great universities and scientific foundations. Though his contributions to American botany and to scientific education in general were extensive and fundamental, he was extremely modest and self-critical. The key to his philosophy of life is found in this gentle and moving inscription carved at his request upon his gravestone:

"To travel hopefully is a better thing than to arrive, and the true success is to labour."—Robert Louis Stevenson.

HARRY J. FULLER

ACADEMY BUSINESS

SECRETARY'S REPORT OF THE BUSINESS OF THE ILLINOIS STATE ACADEMY OF SCIENCE FOR THE YEAR MAY 7, 1949 TO MAY 6, 1950

Compiled by LELAND SHANOR, *Secretary*

The 43rd annual meeting of the Illinois State Academy of Science was held at Rock Island on the campus of Augustana College May 5 and 6, 1950. Attendance at this meeting was somewhat over 500, of whom 319 registered officially, and approximately 400 attended the complimentary Smorgasbord provided by Augustana College to replace the usual Academy banquet. The sectional programs included 105 papers and over 480 people were in attendance at the sectional meetings. At the general session in the morning, Mrs. Jennie N. Smythe delivered an address on "A National Policy on Television" which was prepared for the Academy by her husband, Dr. Dallas W. Smythe, Institute of Communications Research, the University of Illinois, who at the last minute was unable to be present. Following the traditional Swedish Smorgasbord in the evening, the Augustana Choir, under the direction of Mr. Henry Veld, presented a very excellent program which contributed much to the pleasure of all attending the meeting. This concert was followed by a lecture on "Aboriginal Australia," illustrated with Kodachrome movies, by Mr. Frank M. Setzler, Head Curator of the Department of Anthropology, U. S. National Museum. The auditorium of the College Chapel was completely occupied for the concert and the annual lecture, except for a few seats in the balcony.

Those attending the annual meeting this year seemed to be in general agreement that, through the very gracious hospitality of Augustana College, the Rock Island High School, and the various other organizations in the tri-city area which contributed, the 1950 meeting can be regarded as one of the outstanding annual meetings of the Academy.

The past year, in many respects, has been a very good one for the Academy. Our membership has increased by approximately 150 new members. The Constitution and By-laws were carefully studied and a revision was passed unanimously by the Academy at the afternoon business meeting on May 5, attended by approximately 125 members. The revised Constitution and By-laws are attached as a part of the Secretary's report on Business of the Academy.

COUNCIL MEETINGS

The Council held four meetings during the past year. Dr. Thorne Deuel, newly elected President of the Academy, presided at the first meeting which followed the Council Breakfast, Saturday, May 7, 1949, in Galesburg. The invitations extended by Navy Pier and Augustana College to hold the annual meeting in May 1950 on their campuses were considered. The Council decided to accept the invitation of Augustana College and the Rock Island community, and Professor F. M. Fryxell, of Augustana College, was designated Second Vice-President of the Academy, to be in charge of local arrangements. It was suggested that the Academy establish a registration fee and provide such things as identification badges, etc., for members attending the meeting. The fee was left to be considered at a later council meeting, but the matter of items, such as badges, to be provided at the meeting was approved by the Council. The

Council passed a motion that the two best papers, or abstracts of papers, presented at the Collegiate Section, be included in the TRANSACTIONS. The general concensus of the Council seemed to favor the publication of two papers, if such papers were deemed worthy of publication when considered by the Committee on Publications.

The second meeting of the Council was held in Springfield, on October 22, 1949, with President Thorne Deuel presiding. The Council voted that a registration fee of 50c be charged those attending the meeting and that, at the time of registration, registrants be given copies of the program, information about the local community, and other materials that might be appropriate for the meeting. The Council also voted to print the names of sustaining members on the program of the annual meeting and urged the committee on sustaining memberships to endeavor to increase sustaining memberships to make additional funds available for Junior Academy activities. The Council considered a suggestion that the Constitution and By-laws needed revision and a committee was appointed to make such a study and to report the suggested revisions for Council approval at its next meeting in time to have a revision ready to submit for the action of the membership at the annual meeting in May at Augustana College. Following the report of the Chairman of the Conservation Committee, the Council approved a motion to go on record as favoring conservation of small areas and that the Academy might actively participate, as far as it could, in such projects. The attention of the Council was called to the severity of a disease of oaks, known as Wisconsin Oak Wilt, which is spreading into Northern Illinois, and is becoming an increasing menace to our native oak stands. The Council approved a motion that a letter, drawn up by Dr. L. R. Tehon and expressing the Council's feeling in the matter, be sent to certain government agencies, urging that additional funds be made available for the study of the disease and possible methods of controlling it.

President Thorne Deuel presided at the third meeting of the Council, held in Springfield on January 14, 1950. Reports of sectional chairmen on the progress being made in arranging the program for the annual meeting, a report by Dr. Fryxell on arrangements at Augustana College in Rock Island, and reports of chairmen of certain of the standing committees were presented. A preliminary report of the actions of the committee on the revision of the Constitution and By-Laws was given and several suggestions by members of the Council were incorporated in the draft which had been prepared. With these suggestions incorporated, the committee was directed to prepare copies of the revision to send to the membership, along with the program of the annual meeting, so that it could be acted upon at Rock Island. Because of the continued growth of the Junior Academy, certain problems have developed. Mr. George S. Porter, the General Chairman of the Junior Academy, suggested a plan whereby the State might be divided into regions for the purpose of holding regional exhibits prior to the annual meeting. Winners of these regional fairs then would bring their exhibits to the annual meeting. The General Chairman of the Junior Academy was authorized by the Council to proceed immediately with this plan, since similar plans have worked very well in other areas, such as music, debate, and similar activities.

The fourth meeting of the Council was held in Rock Island following the annual Council Dinner. President Deuel presided, and 24 people were present for this Council meeting. Sectional chairmen presented their final reports and the General Chairman of the Junior Academy reported on the program of that group. He pointed out that the proposed regional exhibits could not be initiated this year but would be attempted for 1951. Dr. Fryxell reported on local arrangements and called attention to certain changes that were necessary at the last minute. Dr. O. B. Young

presented a report to the Council for the Committee on the History of the Illinois State Academy of Science and had, for the approval of the Council, a manuscript on the early history of the Academy prepared by the chairman of the committee, Mr. W. M. Bailey. He asked that it be published in the Transactions of the Academy, since this early history of the Academy is no longer generally available. The Council approved the publication of this paper in the forthcoming issue of the Transactions. The Council went over the revision of the Constitution and By-laws as presented to the membership and had further changes to suggest before the revised copy was to be presented at the business meeting on Friday afternoon for Academy action.

REPORT OF THE TREASURER

For the Year May 1, 1949 to April 30, 1950

Balance on hand April 30, 1949	$ 1,051.53	
Less outstanding checks	4.81	
True Cash Balance		$ 1,046.72

Receipts

Dues:		
Annual members	$ 1,449.50	
Affiliated societies	4.00	
	1,453.50	
Interest on Meyer real estate	9.00	
Interest from U. S. Savings Bonds, Series G	37.50	
Libraries	2.00	
Sales of Transactions	14.00	
Sales of Reprints	110.40	
Research Grant by the A.A.A.S.	245.00	
Junior Academy—Sustaining memberships	270.00	
		2,141.40
Total Receipts		$ 3,188.12

Expenditures

Council Dinner and Breakfast—Galesburg	$ 73.19	
Local Chairman's Expenses	45.49	
Council Expenses During Year	77.06	
Treasurer's Office Expenses	25.50	
Secretary's Office Expenses	23.61	
Librarian's Expenses	104.56	
Section Chairmen's Expenses	8.04	
Science Talent Search Expenses	19.12	
Conservation Council	3.00	
Corporation Registration	3.00	
Secretary, Honorarium	150.00	
Editor, Honorarium	150.00	
Research Grants	245.00	
Junior Academy	419.71	
Total Expenditures		$ 1,347.28
Balance in Commercial National Bank of Peoria		1,840.84
		$ 3,188.12

Statement of Resources, April 30, 1950

Balance in Commercial National Bank of Peoria	$ 1,840.84
Certificate of Interest for Meyer Block Leasehold	Value Unknown
United States Savings Bonds, Series G	1,500.00
Total Resources	$ 3,340.84

(Signed) W. W. Grimm, *Treasurer*

REPORT OF THE COMMITTEE ON AUDITING

To The Illinois State Academy of Science:

Your committee on auditing respectfully submits the following report:

We have examined the records of the Treasurer, W. W. Grimm, for the year May 1, 1949 to April 30, 1950, and find them correct. The present financial status of the Academy is as follows:

Cash on deposit with the Commercial National Bank of Peoria	$ 1,840.84
Series G, U. S. Savings Bonds, fifteen (15)	1,500.00
Meyer Block Leasehold Certificate No. 15	(Value Unknown)
Assets	$ 3,340.84

(Signed) F. W. LUTTEY, *Chairman*
ALLAN K. SMITH
L. P. ELLIOTT

REPORT OF THE COMMITTEE ON RESOLUTIONS

Your Committee on Resolutions wishes to submit for your consideration the following resolutions:

I. The Illinois State Museum

Be it resolved, that the Illinois State Academy of Science hereby reaffirms its interest in the Illinois State Museum and the construction at the earliest possible date of a suitable and adequate State Museum building.

II. Junior Academy

Whereas—For several years Mr. George S. Porter has served as General Chairman of the Junior Academy of Science, with the full approval and cooperation of the J. Sterling Morton High School, of Cicero, and has achieved notable results in the stimulation of student interest and participation in science; therefore,

Be it resolved, that the Illinois State Academy of Science on the occasion of its 43rd annual meeting does express to Mr. Porter personally and to the J. Sterling Morton High School its appreciation for an outstanding contribution to the education of the youth of Illinois.

III. Rock Island Arsenal

Be it resolved, that the Illinois State Academy of Science expresses to Col. W. W. Warner, commandant of the Rock Island Arsenal, and to the Army Engineers its appreciation of the unusual opportunity to visit and inspect the Arsenal, during the occasion of the 43rd annual meeting of the Academy.

IV. Deere and Company

Be it resolved, that the Illinois State Academy of Science expresses to officials of Deere and Company its appreciation of the unusual opportunity afforded the Academy, on the occasion of its 43rd annual meeting, to visit and inspect the Company's plant at Moline, Illinois.

V. Davenport Museum

Be it resolved, that the Illinois State Academy of Science expresses its appreciation to Mr. Fred Hall, Director of the Davenport Public Museum, for courtesies to the Archeological Section, on the occasion of the 43rd annual meeting of the Academy.

VI. Mr. Carl Gamble

Be it resolved, that the Illinois State Academy of Science extends sincere thanks to Mr. Carl Gamble for courtesies rendered the Academy and especially for the opportunity to visit his astronomical observatory on the occasion of the 43rd annual meeting of the Academy.

VII. Rock Island High School

Be it resolved, that the Illinois State Academy of Science expresses its appreciation to the Principal, Mr. Owen B. Wright, of the Rock Island High School, to Mr. George McMasters, Biology Teacher and local chairman for the Junior Academy, and to their collaborators for many labors contributing to the success of the Junior Academy exhibits and other sessions on the occasion of the 43rd annual meeting of the Illinois State Academy of Science.

VIII. Chamber of Commerce

Be it resolved, that the Illinois State Academy of Science expresses its appreciation to Mr. W. L. Keepers, Secretary of the Rock Island Chamber of Commerce, for many courtesies rendered during the 43rd annual meeting of the Academy at Augustana College.

IX. Junior Academy Banquet

Be it resolved, that the Illinois State Academy of Science expresses its grateful appreciation to the ladies of St. John's Lutheran Church, who under the leadership of Mrs. George Myer provided the banquet for the Junior Academy on the occasion of the 43rd annual meeting of the Academy, at Augustana College.

X. Augustana College

Whereas: Augustana College, through its Board of Directors, its President, Dr. Conrad Bergendoff, Professor F. M. Fryxell, Chairman, and the several and individual members of the Committee on Local Arrangements, has so cordially invited the Illinois State Academy of Science to hold its present and 43rd annual meeting on the Augustana College campus during the 75th anniversary of the founding of the College, and

Whereas: the College, Dr. Fryxell and his committee, and many faculty members and students have labored diligently to provide necessary facilities and make needed arrangements, and have given generously in time and effort to bring about an outstandingly successful meeting; therefore,

Be it resolved, that the Illinois State Academy expresses its sincere thanks for all efforts in its behalf, adds its compliments on arrangements especially well planned and carried out, and expresses its deep appreciation of the exceptionally cordial and gracious hospitality that has been offered.

XI. Smorgasbord

Be it resolved, that the Illinois State Academy of Science extends hearty and appreciative thanks to Mrs. David Beckstrom and her assistants for planning preparing, and serving the traditional Swedish Smorgasbord, an outstanding and happy feature of the 43rd annual meeting of the Academy at Augustana College.

XII. Augustana Choir

Be it resolved, that the Illinois State Academy of Science, on the occasion of its 43rd annual meeting, expresses its grateful appreciation to Mr. Henry Veld, conductor, and the Augustana Choir for an outstanding musical contribution to this meeting of the Academy.

XIII. Augustana College Band

Be it resolved, that the Illinois State Academy of Science, on the occasion of its 43rd annual meeting, expresses its grateful appreciation to Mr. Robert D. Gaskill, conductor, and the Augustana College Band for an outstanding musical contribution to this meeting of the Academy.

XIV. Secretary

Be it further resolved, that the Secretary is instructed duly to enter the foregoing resolutions on the minutes of the Academy and to transmit copies of the several resolutions to the parties concerned.

(Signed) LEO R. TEHON, *Chairman*
HARRY J. FULLER
CLARENCE R. SMITH

REPORT OF THE NECROLOGY COMMITTEE

Whereas: During the past year the Illinois State Academy of Science lost, by death, the members listed below:

A. J. Demster
R. E. Harris
C. R. Moulton
Clarence O. Sappington
Emil A. Siebel
A. M. Simpson
Neil E. Stevens
L. O. Trigg

Be it resolved: (1) That the Academy expresses its grief over their passing, and (2) That it extends its sincere sympathy to their families, to whom the Secretary is directed to write letters indicating our sense of loss while we extend our sincere sympathy.

(Signed) A. GILBERT WRIGHT
GEORGE D. FULLER

CONSTITUTION AND BY-LAWS ILLINOIS STATE ACADEMY OF SCIENCE

(Revised through May 5, 1950)

CONSTITUTION

Article I. Name

This Society shall be known as The Illinois State Academy of Science.

Article II. Objects

1. The objects of the Academy shall be the promotion of scientific research, the diffusion of scientific knowledge and scientific spirit, and the unification of the science interests of the state.

Article III. Members

1. *Active members* have the privilege of: Attending meetings, voting, holding office, presenting papers at meetings of the Academy, having such published if they are accepted by the Committee on Publication, and receiving copies of all publications of the Academy. Active members of the Academy shall be as follows:

   a. *Life members* shall be those who have paid fifty dollars to the Academy as life membership dues, or have completed the payment of the stipulated requirement for life membership before May 6, 1950. Life membership dues shall be placed as a permanent fund and only the income is to be used.

   b. *Annual members* shall be those who pay the annual membership dues.

2. *Student members* shall be those undergraduate college students who are elected to membership on recommendation of a college faculty sponsor who is a member of the Academy. Student members shall have the privileges of active members except they may not hold elected office in the Academy.

3. For election to active or student membership, the candidate's name must be proposed by two members, be approved by a majority of the Committee on Membership, and be acted upon favorably by a majority vote of the Council.

4. The dues for annual membership in the Academy shall be two dollars per year. Annual dues for student members shall be one dollar.

5. *Sustaining members* shall be those individuals or affiliated societies or other organizations who pay an annual dues of ten dollars or more. Funds derived from sustaining memberships are to be used by the Academy to help further the program of the Junior Academy in such manner as the Council of the Academy shall determine by majority vote.

6. *Charter members* are those who attended the organization meeting in 1908, signed the Constitution, and paid dues for that year.

Article IV. Officers

1. The *elected officers* of the Academy shall be a President, a First Vice-President, a Secretary, and a Treasurer. These officers shall be chosen by ballot at the time of the annual meeting and shall hold office for one year, or until their successors qualify.

2. The above officers shall perform the duties usually pertaining to their respective offices.

3. Ex-officio and appointive officers shall be a Second Vice-President, a Librarian, and Delegates to the A.A.A.S. and to the Conservation Council.

4. The *Second Vice-President*, who may be a resident of the community in which the next annual meeting is to be held, shall be appointed by the Council each year when the place of the next meeting has been decided upon, in order that he may serve as the ex-officio chairman of the *Committee on Local Arrangements*.

5. The Chief of the State Museum Division of the Department of Registration

and Education of the State of Illinois shall be the *Librarian* of the Academy.

6. The *Librarian* shall have charge of all the books, collections, and material property of the Academy, and shall serve as archivist of all official records and documents of the Academy. The Librarian shall have charge of the distribution, sale, and exchange of the published *Transactions* of the Academy under such restrictions as may be imposed by the Council.

7. *Auditing Committee.* The presiding officer shall, prior to each annual meeting, appoint a committee of three who shall examine and report in writing upon the accounts of the *Treasurer.*

8. Three *recent past officers* of the Academy shall be elected to serve as active members of the Council of the Academy.

Article V. Council

1. The Council shall consist of the elected officers of the Academy, the Second Vice-President, the Librarian, three recent past officers of the Academy, the General Chairman of the Junior Academy, and the Coordinator of the Collegiate Section. It shall be the duty of the Council to plan the annual meetings. To the Council shall be entrusted the management of the affairs of the Academy during the intervals between regular meetings.

2. The Council shall meet on call by the President of the Academy.

3. The Council shall ordinarily hold four meetings during the year, one just prior to the annual meeting of the Academy, one as shortly after the annual meeting as is convenient, and two others, normally in November and January.

Article VI. Meetings of the Academy

1. The regular meetings of the Academy shall be held at such time and place as the Council may designate. Special meetings shall be called by the President upon written request of twenty members.

Article VII. Publications

1. The regular publication of the Academy shall be the *Transactions* of the Academy.

2. The payment of dues entitles all members, except in the case of emergency, to receive the currently published *Transactions* of the Academy, but no member in arrears shall receive the published *Transactions* of any year for which he is or remains in arrears.

Article VIII. Foundation Fund

The Treasurer shall maintain a permanent fund for the Academy, only the interest on which may be used. This permanent fund shall consist of (1) life membership dues, (2) donations, and (3) funds as the *Council* may see fit from time to time to add from accumulations in the treasury.

Article IX. Affiliation

The Academy may enter into such relations of affiliation with other organizations of appropriate character as may be recommended by the *Council*, and may be ordered by a three-fourths vote of the members present at any regular meeting.

Article X. Amendments

This constitution may be amended by a three-fourths vote of the membership present and voting at an annual business meeting, provided that notice of the proposed change has been sent by the Secretary to all members at least twenty days before such meeting.

BY-LAWS

I. Order of Business

The regular order of business shall include the following:

1. Call to order
2. Reports of officers
3. Reports of standing committees
4. Election of members
5. Reports of special committees
6. Appointment of special committees
7. Unfinished business
8. New business

9. Election of officers
10. Program
11. Adjournment

II. Notice of Meetings

No meeting of the Academy shall be held without thirty days previous notice by the Secretary to all members.

III. Quorum

Fifteen members shall constitute a quorum of the Academy. Six members of the Council shall constitute a quorum of the Council.

IV. Incurrence of Bills

No bill may be incurred against the Academy by officers or committees in excess of twenty-five dollars, except as provided for in By-law X, unless approved by the President and the Secretary.

V. Dues

1. Dues are payable on or before the date of the annual meeting.

2. Members who, after having been duly notified by the Treasurer, shall fail to pay their dues on or before the date of the annual meeting of any year shall be considered in arrears and if they remain so shall have their names stricken from the membership roll on December 31st of that year.

VI. Standing Committees

1. The standing committees of the Academy shall be a Committee on Budget, a Committee on Affiliations, a Committee on Conservation, a Committee on Membership, a Committee on Publications, a Committee on the Junior Academy, and such others as the Academy shall from time to time deem desirable.

2. These standing committees shall consist of members chosen annually by the Academy, except for the Committee on Publications.

3. The Committee on Publications shall be appointed by the Council of the Academy and shall consist of six members representing several Sections of the Academy. Two members of this committee shall be appointed for terms of three years, two members for terms of two years, and two for a term of one year. As terms of these members expire, the Council at its meeting just prior to the annual meeting of the Academy, shall make appointments for three year terms. In case of a vacancy the Council shall appoint someone to fill the unexpired term.

4. The Committee on the Junior Academy shall manage the affairs of the Junior Academy with the advice and approval of the Council of the Academy.

5. The Coordinator of the Collegiate Section, who is elected by the Academy, with the assistance of a committee if it seems desirable, shall cooperate with the officers elected by the Collegiate Section in conducting the affairs of that body, subject to the advice and approval of the Council.

VII. Sections of the Academy

1. For the annual meeting of the Academy, there may be Sections for the presentation of programs as follows: Anthropology, Botany, Chemistry, Geography, Geology, Physics, Psychology and Education, Social Sciences, Zoology, Collegiate.

2. Other sections may be added on request by ten active members of the Academy and with the approval of the Council.

3. Members of the Academy shall indicate in which section or sections they are particularly interested.

4. Those members present at any section meeting during the annual meeting of the Academy shall constitute a quorum of the section.

5. They shall elect a chairman for the ensuing year.

VIII. Editing of Publications

1. The editing of the *Transactions* and of any other publications which the Academy may authorize shall be a responsibility of the Committee on Publications. It shall be the duty of this committee to pass on the merit of papers submitted for publication, select a technical editor, and establish, with the approval of the Council, editorial policy.

2. A Technical Editor of the *Transactions* shall be appointed by the Council upon recommendation of the Committee on Publications. The Technical Editor shall receive a small honorarium, the amount to be determined by the Council and approved by the Academy. The Technical Editor shall carry out policy determined by the Committee on Publications.

IX. Regulations Regarding Papers

No paper shall be entitled to a place on the program unless the manuscript or an abstract of the same shall have been previously delivered to the Secretary. No paper shall be presented at any meeting by any person other than the author, except on vote of the members present at such meeting. Manuscripts of papers intended for publication must be handed to the Secretary at the time of the annual meeting. Except by invitation of the Council, no paper can be accepted for publication unless the author is a member of the Academy or an applicant for membership. No paper shall be accepted for publication which has already been published elsewhere.

X. Officers' Expenses

The Secretary and the Treasurer shall have their expenses paid from the treasury of the Academy while attending Council meetings and annual meetings. Other members of the Council may have their expenses paid while attending meetings of the Council, other than those in connection with annual meetings.

XI. Robert's Rules of Order

Robert's Rules of Order shall cover all situations not specifically provided for in the Constitution or By-laws of the Academy.

XII. Suspension or Amendment of By-laws

These by-laws may be amended or suspended by a majority vote of the members present and voting at any business meeting.